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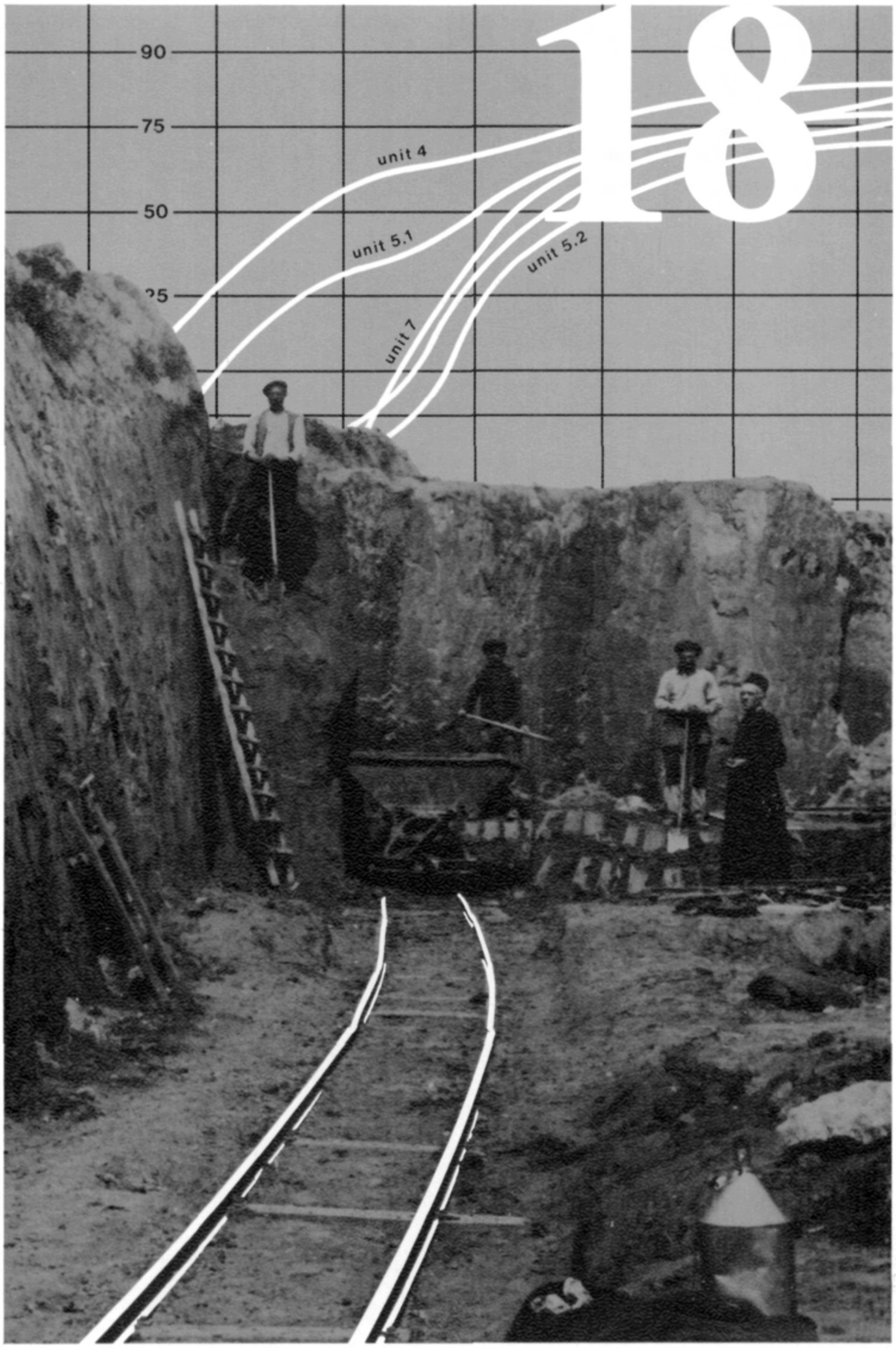

1985

ANALECTA
PRAEHISTORICA
LEIDENSIA

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PUBLICATIONS OF THE INSTITUTE OF PREHISTORY
UNIVERSITY OF LEIDEN

LEIDEN UNIVERSITY PRESS 1985

reprinted from: Mededelingen Rijks Geologische Dienst N.S. 39 (1985)

redactiecommissie: C.C. Bakels en L.P. Louwe Kooijmans

redactie van dit nummer: Th. van Kolfschoten *en* W. Roebroeks

omslagontwerp: H.A. de Lorm

foto omslag: Belvédère groeve ca. 1930.
Gemeentelijke Archiefdienst Maastricht

ISBN 9004.079 068

ANALECTA PRAEHISTORICA LEIDENSIA 18

MAASTRICHT-BELVÉDÈRE: STRATIGRAPHY, PALAEOENVIRONMENT AND ARCHAEOLOGY OF THE MIDDLE AND LATE PLEISTOCENE DEPOSITS

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CONTENTS

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PREFACE

The papers published in this volume of the Mededelingen van de Rijks Geologische Dienst concern a remarkable and extremely interesting site, Belvédère, near the city of Maastricht in the province of Limburg, The Netherlands.

Modern Quaternary research is highly multidisciplinary in character, although it should be said that even the early work on important sites of Quaternary age tended to combine the efforts of geologists, palaeontologists, and prehistorians. This is quite natural, because the Quaternary period was characterized by ice ages and marks the emergence of mankind.

The Belvédère site and its environs first attracted attention in the early nineteenth century, when geological research began in this area. After a period of diminishing interest in the site, some lucky finds of palaeolithic artifacts - found around 1980 by several open-minded enthusiasts, both amateurs and professionals - led to systematic archaeological excavations by a team representing many disciplines. In 1982, the INQUA National Committee for The Netherlands organized a symposium at the Museum of Natural History in Maastricht, during which the first results of the excavations were presented. Since then much additional information has been collected about the section and especially the relative and absolute ages of the main artifact-bearing horizon. As chairman of the INQUA National Committee for The Netherlands I have followed with pleasure the harmonious cooperation of so many people, amateur and professional archaeologists, palaeontologists, sedimentologists, and other specialists from not only The Netherlands but also other countries. The contribution of a number of research institutes should be mentioned here, i.c., the Instituut voor Prehistorie (Leiden), the Instituut voor Aardwetenschappen (Utrecht), the Instituut voor Aardwetenschappen (Amsterdam), the Fysisch Geografisch en Bodemkundig Laboratorium (Amsterdam), and the Rijks Geologische Dienst (Haarlem). Of particular interest, finally, are the possibilities this site offers for absolute dating of the main archaeological horizon. The contributions made by the research institutes of Oxford and Köln deserve special mention in this respect.

At present, the palaeolithic site of Belvédère, which has yielded well-circumscribed *in situ* finds accompanied by many fossils of different kinds, is both the best absolutely dated one in Western Europe and the oldest one known so far in The Netherlands, since it dates from an intra-Saalian warm-temperate interval with an established age lying roughly in the middle of a period which occurred between 200,000 and 300,000 years ago.

It is with great pleasure that I recommend this volume containing the results of a concentrated joint effort in modern Quaternary research.

W. H. Zagwijn,
Chairman, INQUA National
Committee for The Netherlands

THE MAASTRICHT-BELVÉDÈRE RESEARCH: INTRODUCTION

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INTRODUCTION

The Maastricht-Belvédère loess- and gravel-pit is located NW of the city of Maastricht, on the left bank of the river Maas, on the edge of the plateau of Caberg. (fig. 1) The pit was carved into the steep cliff between the Lower and the Middle Terrace of the river Maas.

In September 1980 W. M. Felder (Geological Survey of the Netherlands, Heerlen) discovered a paleolithic artifact in one of the loess-sections in the Belvédère loess- and gravel pit. This discovery inspired the author and two amateur-archaeologists, Kim Groenendijk and Jean-Pierre de Warrimont, to investigate the quarry sections intensively. We found several artifact- and fauna bearing horizons, most of which can be dated to the 'Saalian' of the Netherlands (Zagwijn 1973).

The Belvédère research, which was, initially started as an archaeological project, sponsored by the Institute of Prehistory of Leiden University, has since these initial discoveries developed into a more comprehensive project in which scientists from several disciplines and different countries are cooperating. In this volume of the Mededelingen Rijks Geologische Dienst a first synthetic review of the Belvédère quaternary research is presented.

Fig. 1. Location of the Maastricht-Belvédère pit.

HISTORY OF THE RESEARCH

In the first half of the nineteenth century several loess- and gravelpits existed in the Caberg region. From the 1850s onwards a number of - generally small - brick factories were founded (Archive Municipality Oud-Vroenhoven, Municipal Archive Maastricht). In the nineteenth century the Caberg plateau became known for the fossils found in its quaternary deposits during the construction of the Zuid-Willemsvaart canal in 1823 and from other exposures (Crahay, 1823/24; van den Ende, 1835; Kerckhoffs, 1884; Martin, 1889; Rutot 1893). A human jaw found in 1823, ca 500 m N of the Belvédère pit - published as found under 6.5 m of loess - became known as 'la mâchoire de Maestricht'; the jaw was the subject of a lively international discussion (Crahay, 1823; Schaaffhausen, 1860; Kerckhoffs, 1884; de Mortillet, 1886; Martin, 1889; de Mortillet & de Mortillet, 1910; van Doormaal, 1945; van der Vlerk, 1955). According to the literature Charles Lyell visited the find-locality of the jaw.

Other important finds - now lost - were made in 1815-1817 during the construction of the fortress 'Willem' at the foot of the Caberg plateau Middle Terrace, ca 1.5 km S of the Belvédère site. According to a report by de Burtin, dating from 1818, (Municipal Archive of the City of Maastricht, Ms. collection no. 184) remains of elephant were found, and Habets (1887) also mentions the presence of hippopotamus. The detailed description of the exposure in the manuscript mentioned that the fossils were found under more than 6 meters of loess.

Large scale quarrying in the Belvédère pit started in the 1890s, when Baeten and Lalieu bought considerable areas of land for their Belvédère company, officially established in 1897. The pit soon became locally well known for its loess sections and for fossils collected from the gravels and the loess (Klein, 1913; Klein, 1914; Reinhold, 1916; Reinhold, 1923; Cremers, 1925). Figure 2 shows pictures of the Belvédère pit taken in the thirties when manual exploitation of the loess and gravel favored recovery of fossils; some of these are now curated by the Museum of Natural History at Maastricht.

In the twenties of this century important Neolithic finds with associated features were discovered and excavated at Belvédère; Iron Age and Roman ware were also collected from the pit area in considerable quantity (Kengen, 1928; Disch, 1969; Disch, 1971/1972).

Van Doormaal (1945) paid considerable attention to the Caberg pits; more recently, exposures in the Belvédère quarry were described by Paulissen (1973) and Bosch (1975).

In 1982 an interim report on the interdisciplinary research at Maastricht-Belvédère was presented at a congress on 'Palaeolithic Archaeology and Quaternary Stratigraphy in Southern Limburg', organized by the Dutch INQUA commission. After this congress some preliminary papers on the site have been published: Roebroeks et al., 1983; Roebroeks, 1984.

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Fig. 2 A, B. The Maastricht-Belvédère pit; pictures taken in the thirties of this century (Municipal Archive of the city of Maastricht).

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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).

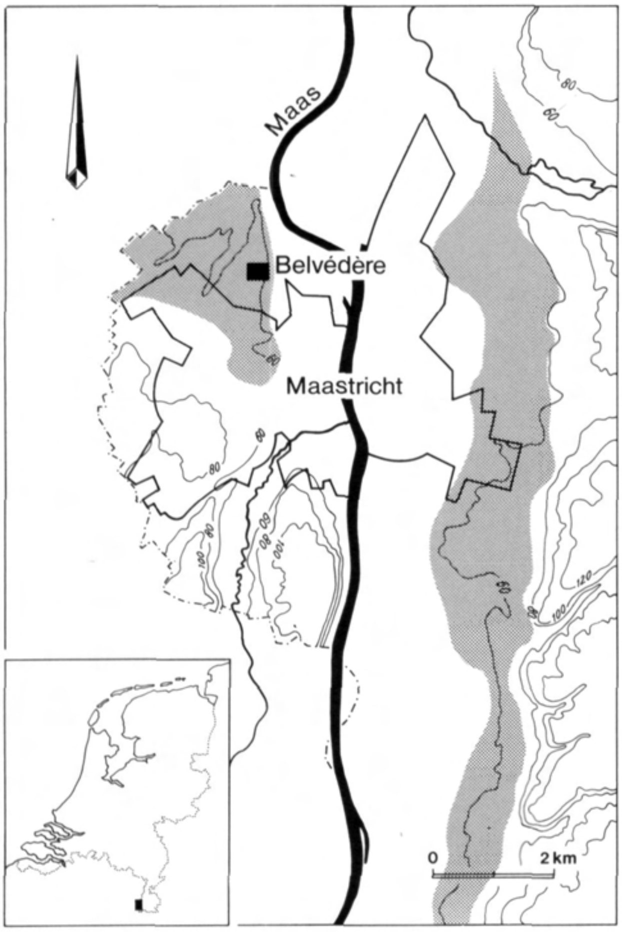

Fig. 1. Location of the Maastricht-Belvédère pit and in gray, distribution of the Caberg Middle Terrace sediments (after: Brueren 1945).

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

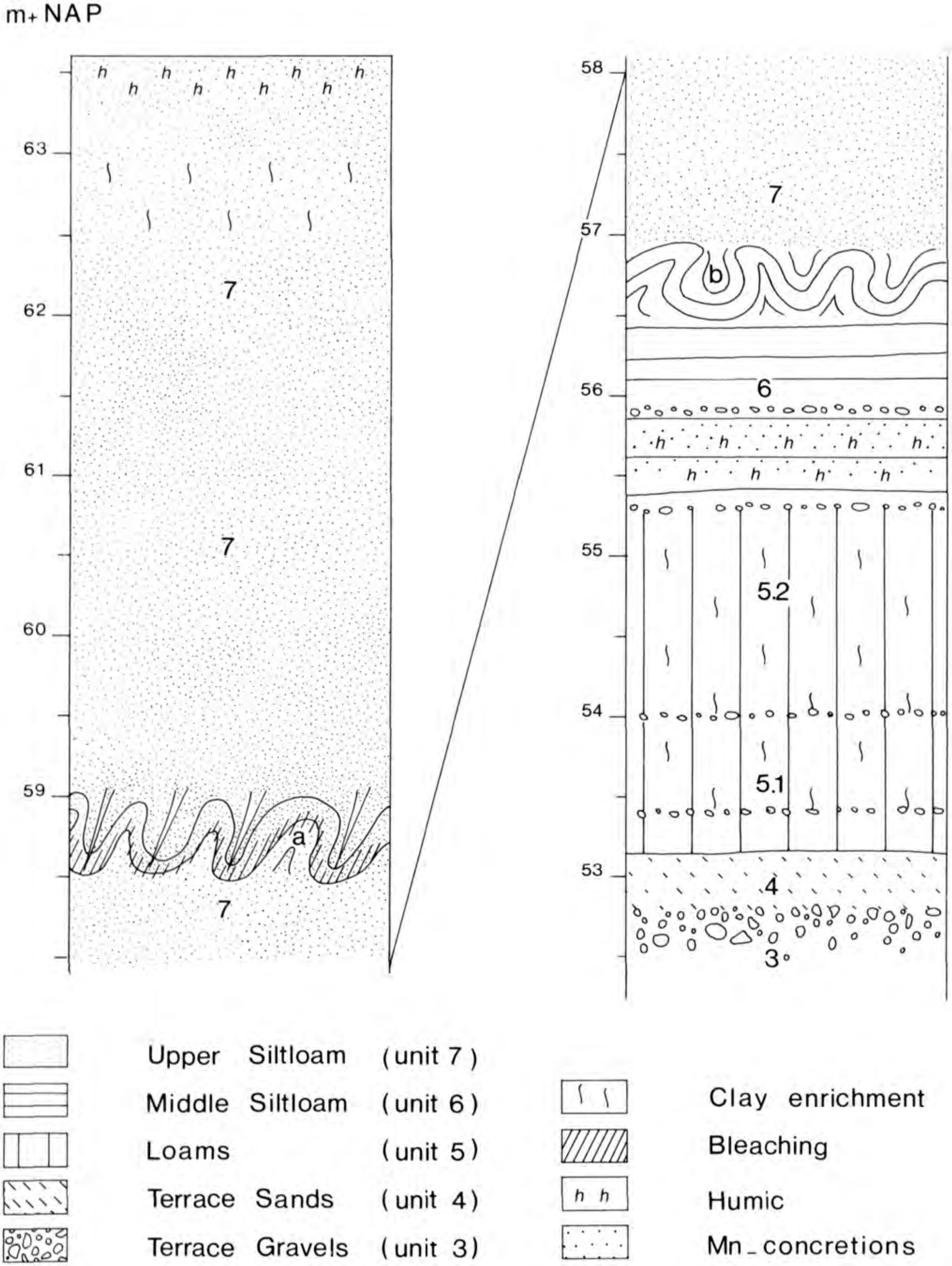

Fig. 2. General lithological sequence of the deposits on top of the terrace gravels in the Belvédère pit.

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,

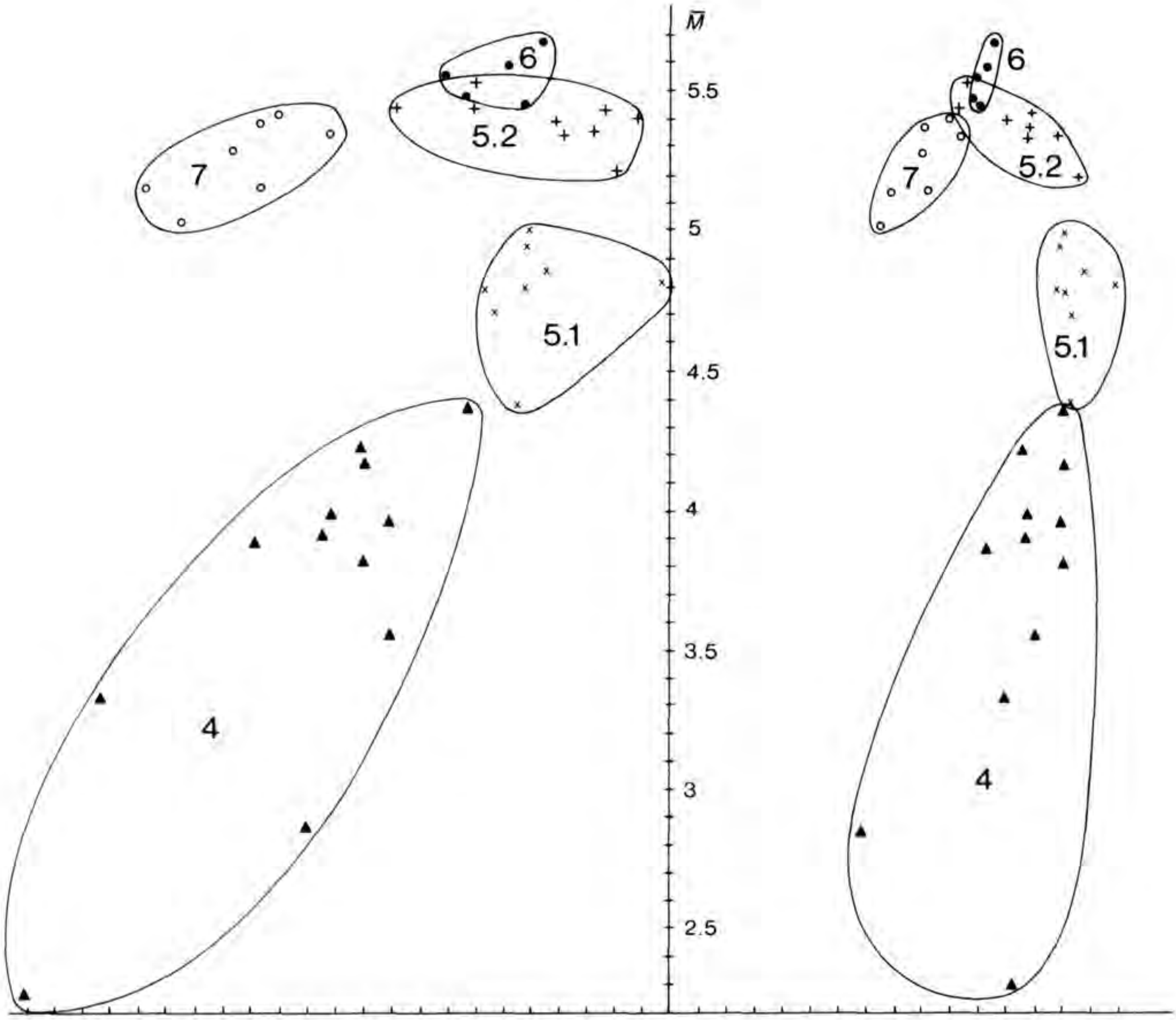

Fig. 3. Grain-size distributions of Units 4, 5.1, 5.2, 6 and 7 as characterized by their mean ($\bar{M}$), standard deviation (σ), and moment of skewness (Sk.).

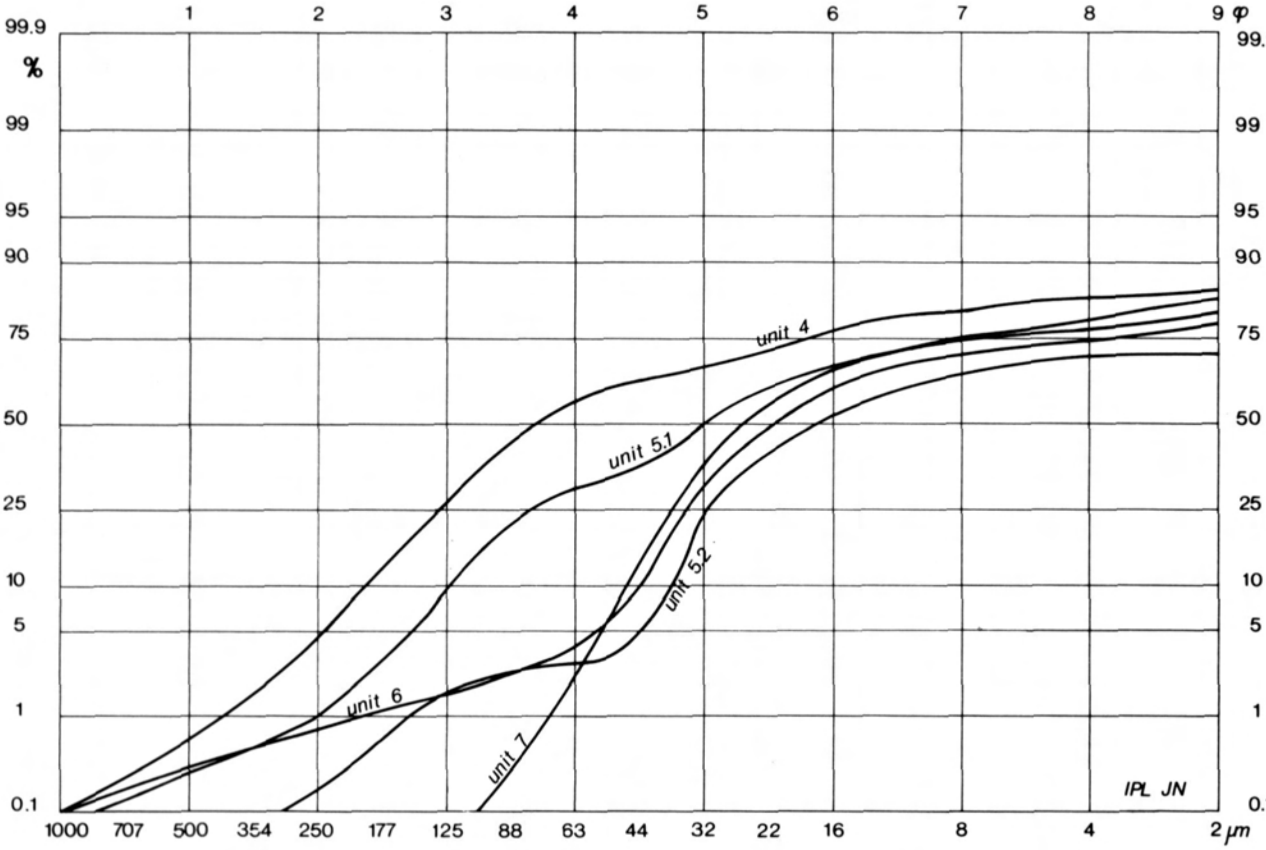

Fig. 4. Cumulative grain-size distribution of Units 4 to 7.

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 (%)		number of samples
		sand	clay	
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 B1 (5.2.) Rocourt (upper part) 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.

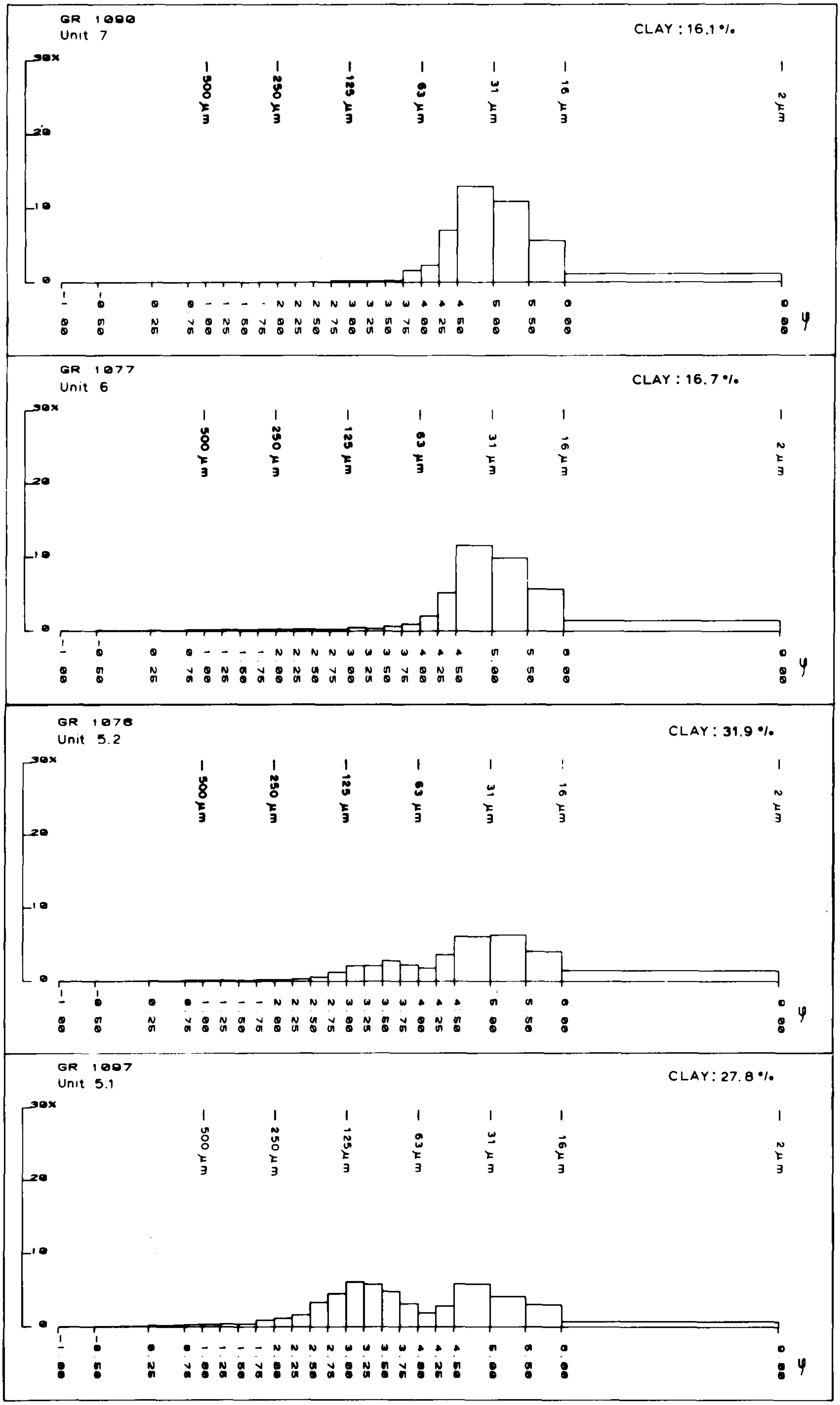

Fig. 5. Comparison of typical histograms of the grain-size distribution in Units 5.1, 5.2, 6 and 7.

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:

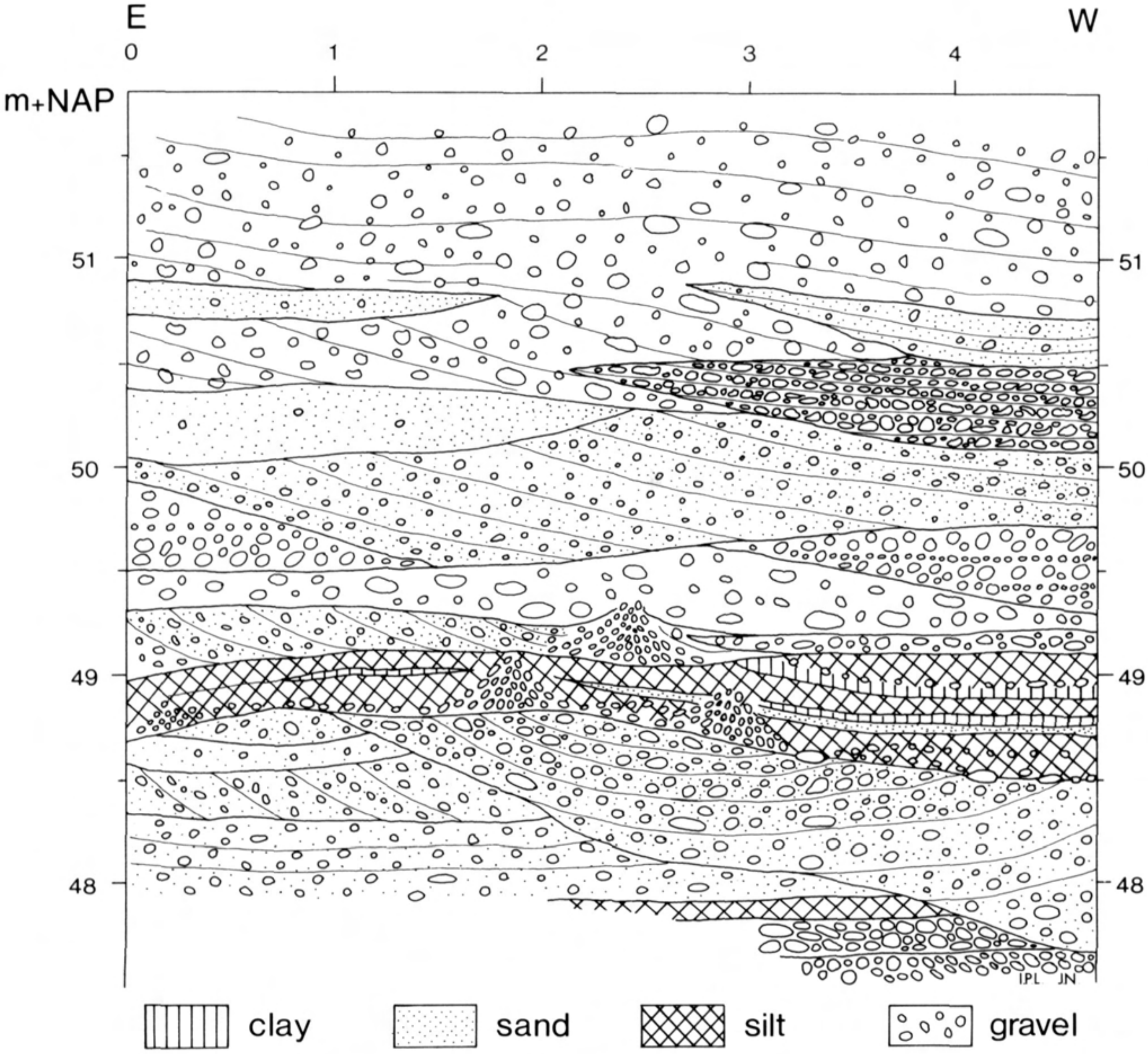

Fig. 6. Representative vertical section of the terrace gravel. Unit 3.

- 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

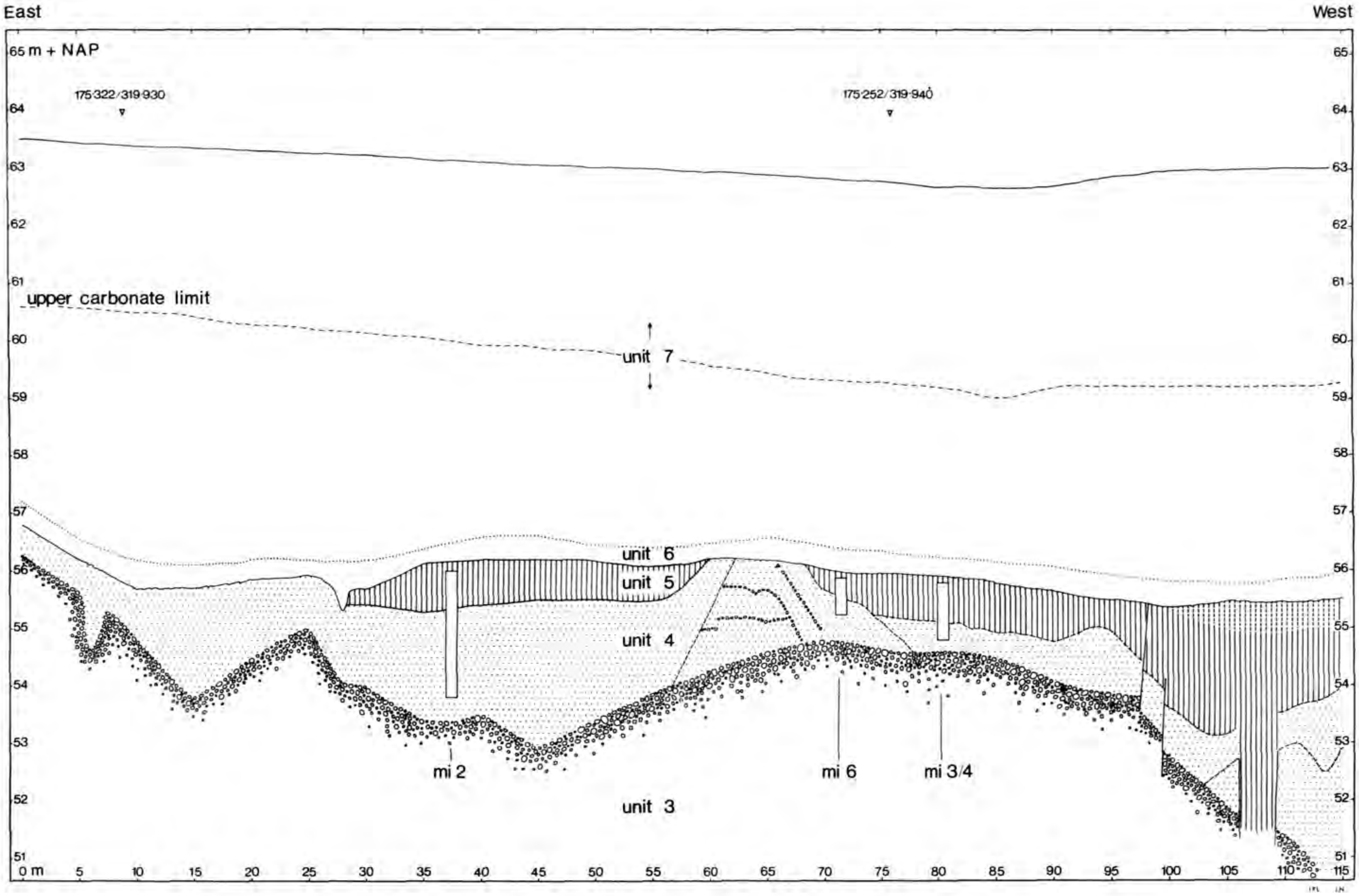

Fig. 7. Idealized E-W cross-section through the Belvédère-pit, with Units 4 to 7 (modified after Felder & Bosch, in: Ruegg, 1982). The vertical bars refer to the stratigraphical location of the micromorphologically investigated profiles (mi 2, mi 3/4, mi 6). The numbers in top of the section refer to 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

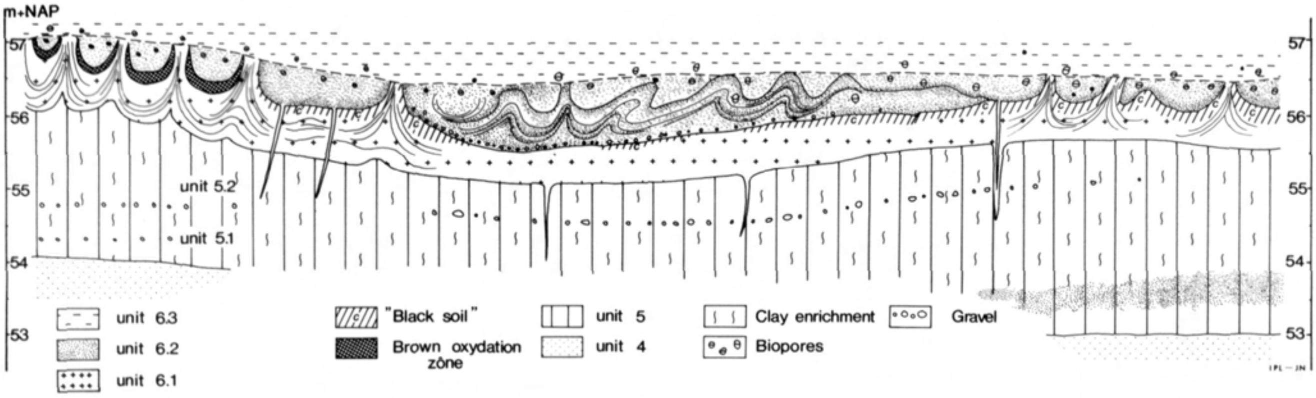

Fig. 8. Detailed vertical section of the lower part of Unit 6 with periglacial deformations and soil development.

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.

ACKNOWLEDGEMENTS

We sincerely thank Dr. A. C. Imeson (University of Amsterdam) and Dr. L. Krook (Free University, Amsterdam) for critical reading of the manuscript and their suggestions for improvement. Thanks are also due to Drs. G. H. J. Ruegg, Mr. P. W. Bosch and Mr. W. M. Felder of the Geological Survey of The Netherlands for permission to use their unpublished field and laboratory data of the Belvédère pit.

To Mr. J. Nederlof and Mr. H. de Lorm (Institute of Prehistory, Leiden University) we are much obliged for making the drawings, and to Mrs. M. Boone, Mr. R. van Elsas, Mr. M. Konert and Mr. P. Wartenbergh for the grain-size analyses in the laboratories of the Institute of Earth Sciences of the Free University of Amsterdam and of the Laboratory of Physical Geography and Soil Science, University of Amsterdam. Mrs. M. van der Sanden (Institute of Prehistory, Leiden University) typed the text.

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MICROMORPHOLOGICAL STUDY OF THE TERRACE SANDS (UNIT 4) AND 'LOAMS' (UNIT 5) AND THEIR PALAEOSOLS IN THE BELVÉDÈRE PIT NEAR MAASTRICHT, SOUTHERN LIMBURG, THE NETHERLANDS

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CONTENTS

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ABSTRACT

The micromorphological study of the Units 4 (Terrace Sands) and 5 ('Loams') in the Belvédère pit revealed that the site mainly can be regarded as a sediment receiving area, with sedimentation during unstable periods (Ku-cycles) and formation of palaeosols during stable periods (Ks-cycles). Three unstable periods are distinguished: K1u, K2u and K3u with deposition of Units 4a-c, Unit 5.1 and Unit 5.2 respectively, mainly in a shallow fluvial and backswamp-like environment and to a lesser extent by sheet flow (rainwash and afterflow).

From the stable periods in between (K1s, K2s and K3s) strongly to moderately truncated buried palaeosols are found. The palaeosol remnants suggest the formation of a well-drained Luvisol on the higher parts and a Gleyic Luvisol in the lower parts of the landscape during the first stable cycle (K1s). Indications for soil formation during the K2s-cycle are very limited, suggesting the presence of a weakly truncated incipient soil or of a strongly truncated Luvisol. During the K3s-cycle the palaeosol remnants suggest formation of a mainly well-drained Luvisol.

This type of soils could be formed in a temperate climate under deciduous forest.

It is suggested that prehistoric man visited the Belvédère site only shortly during the unstable periods.

Tephra layers are not indicated in the pit.

INTRODUCTION

Micromorphological analysis, using thin sections, makes it possible to study under the polarization microscope the components in sediments and soils in their mutual relationship. Features resulting from primary sedimentation can be distinguished from pedological phenomena, as a result of soil formation in the past, e.g. pedorelicts, or due to soil formation in situ after deposition. The pedological features can often subsequently be arranged in their sequence of formation.

The complicated history of Quaternary sedimentation and soil formation is considered to be determined by frequent sharp changes in the environment, resulting from climatic fluctuations.

The K-cycle (K for Kronos = time) concept proposed by Butler (1959) divides the Quaternary period into stable periods (Ks-cycles), dominated by soil formation, and unstable periods (Ku-cycles), dominated by erosion, sedimentation and the formation of slope deposits. From a sedimentary point of view, two types of environment can be recognised in the landscape (see Fig. 1): sediment producing or erosional areas, and sediment receiving areas.

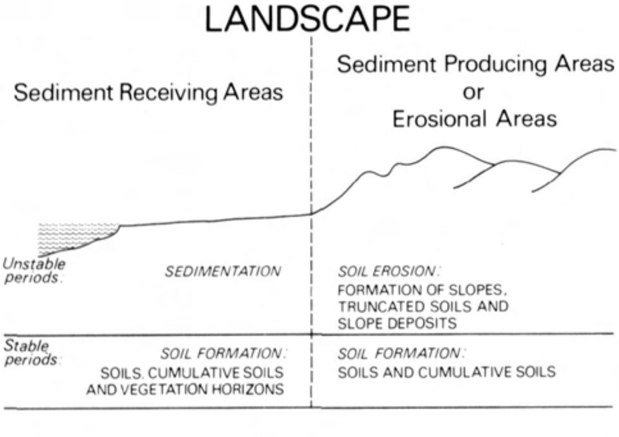


Fig. 1. Schematic presentation of the events in the landscape during stable and unstable periods.

During Ku-cycles in sediment producing areas, as a result of erosion, soil profiles are truncated, and slope deposits are formed. In sediment receiving areas sedimentation occurs and soils are buried, forming so-called palaeosols (e.g. buried soils which have formed in landscapes of the past).

During Ks-cycles in the sediment-producing areas, soil formation keeps pace with removal of material by erosion, and in the sediment receiving areas soil formation occurs during periods of non-deposition or relatively thick soils are formed by deposition of fresh material, forming so-called cumulative soils (Birkeland, 1974; Mücher and Morozova, 1983).

The French geologist Erhart (1956) distinguished two types of periods in geological history. In periods of biological equilibrium, the so-called 'periodes de biostasie', soil formation occurred, whereas in periods of instability, the so-called 'périodes de rhexistasie' most sediments are formed.

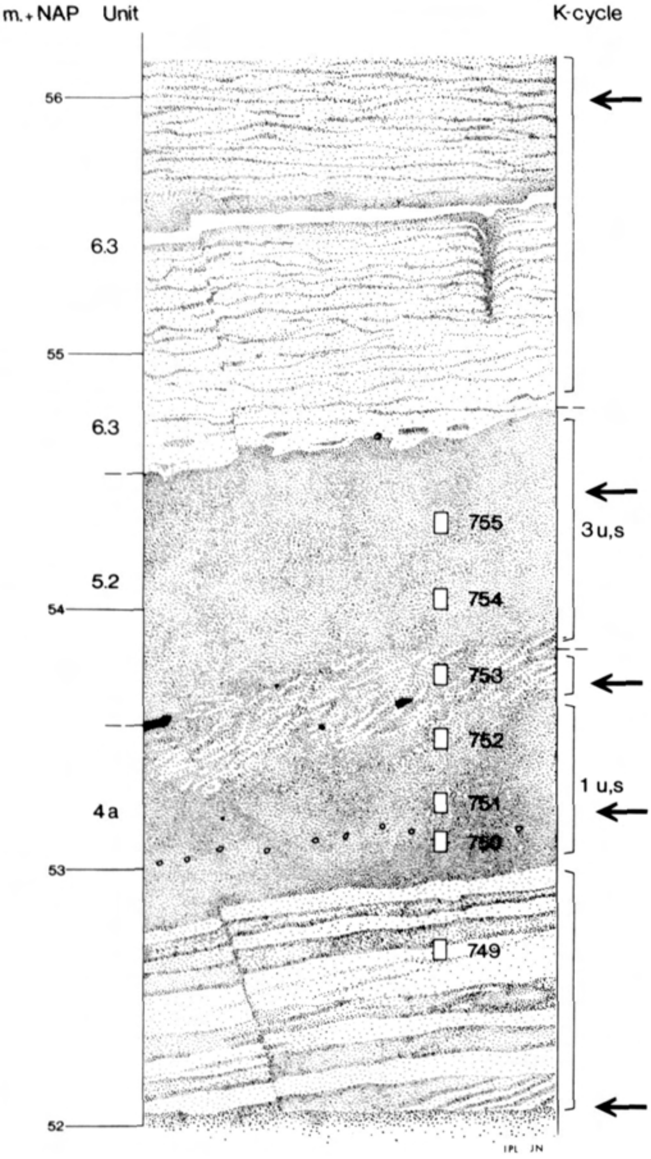
The macromorphological identification of palaeosols in the field is, according to Valentine and Dalrymple (1975, 1976), only possible if they occur in a palaeocatenary sequence, showing an ecological catenary relationship. Such lateral variations in unweathered Quaternary sediments cannot be reproduced by sedimentation and diagenesis. If a palaeocatena is poorly developed or exposed in the field, which often occurs, micromorphology can contribute by identifying the inferred palaeosols either as in situ or as consisting of transported (soil) material (Mücher, 1973a, b; Mücher and Morozova, 1983).

As will be illustrated, the Belvédère site can mainly be regarded as a sediment receiving area with sedimentation during unstable periods and formation of palaeosols during stable periods. However, the occurrence of buried truncated palaeosols in the excavation testify that the site has also acted in the past occasionally as a sediment producing area.

The micromorphological study of the Terrace Sands (Unit 4) and 'Loams' (Unit 5) in the Belvédère pit is firstly focussed on the composition and structure of the sediments, so as to reveal evidence concerning the environmental conditions at the time of their formation during unstable periods. Secondly, attention is given to soil formation after deposition in a stable period, and thirdly to the tracing of features which could be the result of human activity in the past.

METHODS

The field survey was carried out by means of observations in the pit. For the description of soils and sediments use is made of the 'FAO Guidelines for Soil Profile Description' (FAO, 1968), and their colours are



Pale brown (10YR 6/3) laminated silt loam with a gray horizontal layer enclosed, and few frost cracks. Abrupt and wavy boundary with horizon below.

Reddish yellow (7.5YR 6/6) homogeneous silt loam with a massive structure, and a clear and smooth boundary with horizon below.

The mottled zone:
yellowish brown (10YR 6/6) loam with common very pale brown (10YR 7/4) mettles and very few gravel. Clear and smooth boundary with horizon below.

Yellowish brown (10YR 5/6) loamy fine sand grading in upward direction into very fine sandy loam and loam. Occasionally a fine gravel layer subparallel to the surface. Abrupt and smooth boundary with horizon below.

Light yellowish brown (10YR 6/4) and light brownish gray (10YR 6/2 loamy fine sand and fine sand with a lamination subparallel to the surface.

Fig. 2. Profile Mi.2 (archaeological site A at the base of Unit 5.2) at the eastern side of the levee, with the locations of the thin sections, nrs. 749-755.

described according to the 'Munsell Soil Color Charts' (Anonymous, 1954). The soils are classified according to the 'Legend of the Soil Map of the World' (FAO, 1974).

As a matter of fact the soil classifications had to be based on the actual characteristics of the buried soil profiles, which are mostly moderately to strongly eroded, resulting in the disappearance of the A horizons. Consequently the classifications must be regarded as approximations.

For micromorphological study undisturbed samples are taken with tins. The undisturbed samples, first air-dried, and then dried in an oven at 40°C, are impregnated under vacuum with unsaturated polyester resin, Frencken-Synolite, type no. 544-64-0050, using monostyrene as a thinner. To improve impregnation, a pressure of 8 atmospheres is exerted on the samples for one hour with nitrogen, finally followed once again by evacuation of the air. After six weeks of hardening in a fume cupboard the thin sections are prepared following the method described by Jongerius and Heintzberger (1975). The thin sections (8 x 5 cm, occasionally mammoth-sized: 15 x 8 cm, and 20 μm thick) are studied in transmitted light with a 'Leitz' orthoplan polarizing microscope. For the description and interpretation of the thin sections, based on the method and schemes of Bolt and Mücher (1984), the terminology of Brewer (1976) is used, supplemented with terms introduced by van Schuylenborgh et al. (1970).

RESULTS AND INTERPRETATION

The topographical location of the archaeological sites which profiles have been investigated (Mi.1 to Mi.6) is given in Roebroeks (1985), figure 1. The vertical position of Mi.2, Mi.3, Mi.4 and Mi.6 is indicated in the cross-section in figure 7 (Vandenberghe et al., 1985).

Unit 4: Terrace sands

Unit 4a.

Unit 4a occurs in the profiles Mi.2 and Mi.6 (see Figures 2 and 3), situated at the east and west side of the levee respectively.

Sedimentation in the K1u-cycle

The lower part of profile Mi.2 shows that in the first unstable cycle, K1u, sedimentation occurred of mainly fine (100-250 μm) and very fine sand (50-100 μm), and only a few silt-sized particles (2-50 μm), showing only a weak parallel lamination (thin section 749). It contains also silt aggregates with the size of medium to very coarse sand, very few sand-sized rounded nodules of dominantly clay, socalled mud balls (Pettijohn, 1976), and very few fine sand-sized lithorelicts such as shale, sandstone and chert fragments. Only very few thin argillaceous laminae are observed parallel with the surface. In an upward direction (thin sections 750 to 753) lamination is only incidentally observed: - a gravel layer in thin section 750; - thin laminae, (sub)parallel to the surface, consisting of silt-sized grains and covered by a layer of very fine and fine sand grains, less than 2 mm thick in total. Locally, infillings of less than 8 mm deep depressions occur, consisting of a well-laminated deposit of (from below to above): very fine silt and clay particles, silt and very fine sand, and finally completely filled with a mixture of silt, very fine and fine sand. In an upward direction the composition of the matrix material remains the same, albeit that the content of silt-sized grains increases upwards, resulting in loam to silt loam in thin sections 752 and 753. Only locally (thin section 752) do further shale and sandstone fragments occur with the size of medium sand to gravel. In the top of Unit 4a (thin section 753), where silt particles are dominant, still coarser grains occur as medium sand-sized grains up to 450 μm, shale and quartzite fragments up to 700 μm in diameter. Additionally in the top of Unit 4a, a piece (150 x 1100 μm) of a mud crust is observed, composed of clay and fine silt, with a weak unistrial plasmic fabric. The sharp horizontal boundary in the upper part of thin section 753 is regarded as an erosional surface of Unit 4a deposited in K1u-cycle.

The following characteristics of Unit 4a in profile Mi.2: slightly laminated, poorly sorted material with enclosed lithorelicts, soil nodules, mud balls and a gravel layer, suggest that the unit is largely a fluvial deposit. The well-laminated infillings of small depressions could be deposited by afterflow (without raindrop impact) or meltwater flow, compared with the structures obtained by laboratory experiments of Mücher and De Ploey (1977, 1984) and Mücher et al. (1981). In addition, the occurrence of mud crust fragments, the nearly absence of lamination to the top of the unit, and the better sorting in upward direction, could be indications for a decreasing fluvial activity, and an increasing deposition by overland flow and rainsplash activity.

In profile Mi.6 Unit 4a occurs only in the lowest section (thin section 903). The deposit consists mainly of silt and very fine sand and less fine sand, occasionally medium sand-sized grains, embedded in a groundmass of light gray unistrial clay (parallel with the surface) in a porphyric arrangement. Quartzites with a diameter of 200-800 μm occur only locally. Thin, 1 mm thick, laminae parallel to the surface, consisting of very fine and fine sand, occur in the lowest part. In the upper part there are locally laminae of almost pure clay, 50 to 300 μm thick, with a strong unistrial plasmic fabric.

The parallel lamination, the fining in upward direction, and the unistrial fabric of the clay, suggest a low energetic fluvial sedimentation during the beginning of the first unstable cycle (K1u). This could be in agreement with the presumed backswamp-like environment.

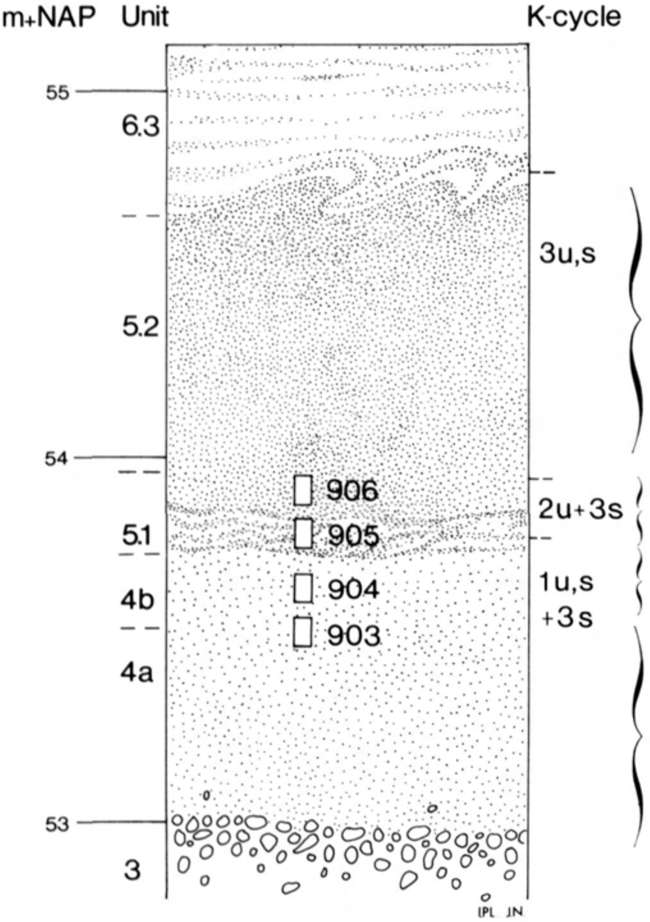
Soil formation in the K1s-cycle

After sedimentation of Unit 4a in the K1u-cycle in profile Mi.2 soil formation occurred during the first stable phase (K1s). The soil is characterized by following micromorphological features:

- biological activity resulted in the formation of biopores by roots and soil animals, pedotubules and matric fecal pellets. Firstly observed in thin section 750 and increasing upwards.
- illuviation of ferriargillans, starting in thin section 749 (in this thin section mainly concentrated in thin horizontal bands), with a maximum in thin sections 751 and 752, and decreasing again in upward direction (thin section 753).
- illuviation of matriargillans, consisting of clay, silt and small amounts of organic matter (van Schuylenborgh et al., 1970), and mainly observed in thin sections 751 and 752,
- papules, e.g. fragments of illuviated ferriargillans, with the same distribution pattern in the profile as the illuviation argillans.
- sharply bounded, rounded ferric nodules, sometimes irregular and angular shaped (thin section 753), mostly present in thin sections 750 till 752.
- very few carbonate nodules in the upper part of the profile (thin sections 752 and 753).
- illuviation cutans of carbonate are only incidentally observed in thin section 752. If occurring together with argillans, the carbonate cutans are observed closest to the remaining void.

The occurrence and distribution pattern of the illuviation cutans strongly suggest that in Unit 4a an argillic horizon has been formed, consisting of a B3t (thin sections 749 and 750), a B2t (thin sections 751 and 752) and a B1t horizon (thin section 753), which is subsequently truncated by erosion in a following unstable cycle, resulting in the disappearance of the A and partly of the argillic horizon. The thin horizontal bands with illuviated clay in the lower part of the profile give rise to the wrong impression in the field that the sediment is strongly laminated.

The matriargillans may be the result of soil degradation in the soil surface horizon. The sharply bounded ferric nodules are regarded not as a formation in situ, but as remnants of an older soil formation in the past, e.g. as pedorelicts, which were present already in the sediment. The absence of hydromorphic phenomena, as sesquioxidic cutans and neocutans, is in agreement with this.



Yellowish brown (10YR 5/6) silt loam. Abrupt and wavy boundary with horizon below.

Light yellowish brown (2.5 Y 6/4), slightly laminated, loam. Abrupt and wavy boundary with horizon below.

Light yellowish brown (2.5Y 6/4) loam with a massive structure and reddish yellow (5YR 6/8) iron mottles. Abrupt and wavy boundary with horizon below.

Light gray (2.5Y 7/2) laminated loamy very fine sand to very fine sandy loam with light yellowish brown (2.5Y 6/4) thin clay laminae.

Fig. 3. Profile Mi.6 at the western side of the levee (archaeological site C in Units 4a and 4b), with the locations of the thin sections, nrs. 903-906.

The carbonate (presumably calcite) nodules and cutans, based on their position in the profile and on the argillans, are regarded as formations in a more recent K-cycle, due to dissolution of carbonates from the overlying calcareous Middle Silt Loam (Unit 6).

The bulk of the papules occurs in a similar way as the illuviation argillans in the profile and resemble each other morphologically. It is suggested that the papules are the result of a disturbance of illuviation cutans mainly by biogenetic pedoturbations, although cryogenic deformations can not be excluded. However, indications for frost action are very limited. Only the silt-capping, as mentioned previously already in thin section 753, can be formed by meltwater after thawing of the surface soil (see Romans et al., 1966; Collins and O'Dubhain, 1980). However, other phenomena, which could be formed by cryogenic processes, mentioned, for example, by Coutard and Mücher (1985), Mücher and Morozova (1983) and Van Vliet-Lanoë et al. (1984), are not observed.

This palaeosol of the first stable phase (K1s), largely based on the presence of a well-drained argillic horizon, is classified as a Luvisol, formed under a deciduous forest in a temperature climate. In the absence of an A horizon this classification can only be tentative.

Indications for human activity are not found in Unit 4a of this profile.

In Unit 4a in the lower part of the profile Mi.6 little soil formation occurs. In the first stable K-cycle (K1s) the pedogenesis is characterized by: reduction of the largest part of the unit, locally iron segregation by oxidation with formation of ferric nodules, additionally few argillaceous papules occur. Biological features are not observed. The papules can be the result of deformation of some illuviated argillans from a horizon above by shrinkage and swelling movements.

Based on the hydromorphic phenomena and the nearly absence of other pedological features, this horizon is classified as a Cg (parent material with gley characteristics), formed in a mainly wet environment.

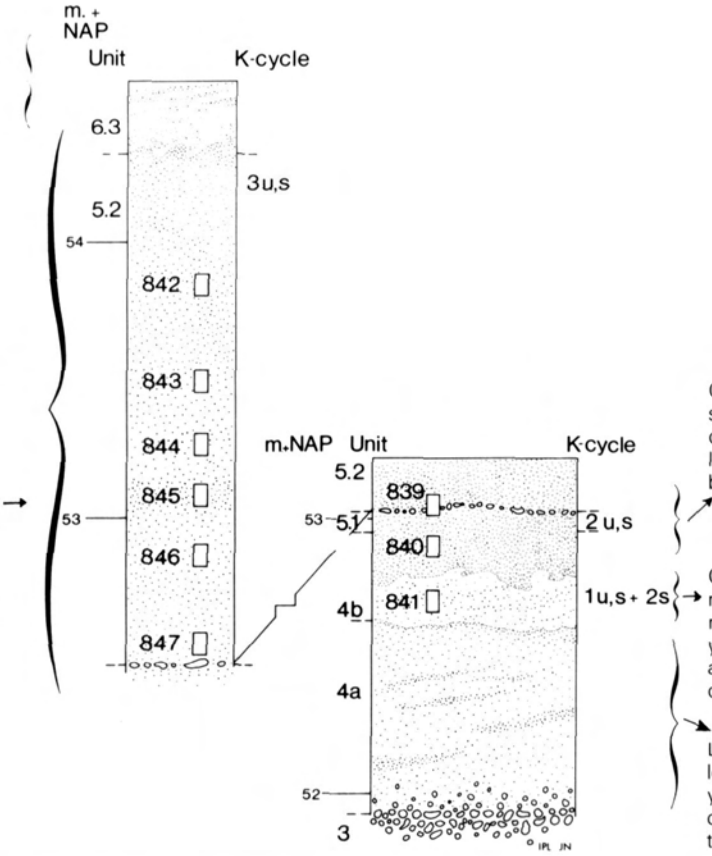
Indications for human activity are not found in this unit.

Units 4b and 4c

Units 4b are sampled in the profiles Mi.6 (Fig. 3) and in profile Mi.3 (Fig. 4) somewhat further to the west. Locally, at site Mi.5, the unit is calcareous (Unit 4c).

Sedimentation in the K1u-cycle

In profile Mi.6 Unit 4b corresponds largely with Unit 4a (thin section 903) of the same profile. The sediment (thin section 904) is somewhat finer textured, only incidentally medium sand-sized grains up to a maximum of 300 μm in diameter are observed. Laminae of sand hardly occur any more, sometimes sand-



Pale brown (10YR 6/3) laminated silt loam with abrupt and wavy boundary with horizon below.

Reddish yellow (7.5YR 6/6), homogeneous silt loam with a massive structure, and abrupt and smooth boundary with horizon below.

Enclosed at a depth of 53.1-53.0 m + N.A.P. (Dutch Ordnance Level-D.O.L.) a horizontal band of brown (10YR 5/3) silt loam with a massive structure. Abrupt and smooth boundaries with horizons above and below.

Olive (5Y 5/3) slightly banded sandy loam and loam with reddish yellow (5YR 6/8) iron mottles, and an abrupt and wavy boundary with horizon below.

Olive (5Y 5/3) silty clay with a massive structure, locally calcareous (Prof. Mi.5) and reddish yellow (5YR 6/8) iron mottles, and an abrupt and wavy boundary with horizon below.

Light gray (2.5Y 7/2) laminated loamy very fine sand with light yellowish brown (2.5Y 6/4) thin clay laminae (less than 5 mm thick).

Fig. 4. Profile Mi.3 (at the right) in a backswamp-like environment (Unit 4b), with the locations of the thin sections, nrs. 841-839. At the left profile Mi.4 in Unit 5.2 ('Loams'), consisting of mainly homogeneous silt loam with the locations of the thin sections, nrs. 847-842, and a gravel layer at the base (archaeological site B with artefacts in Units 4b and in the base of Unit 5.2).

sized grains are observed in clusters. Lithorelicts are not observed. (Sub)horizontal and vertical planes occur, and locally also vughs. The skeleton grains are embedded in a groundmass of light gray unistrial clay (parallel with the surface) in a porphyric arrangement.

The unistrial fabric of the clay and the continuation of fining in an upward direction is similar to that seen in thin section 903, suggesting also fluvial deposition during the first unstable cycle (K1u) in a backswamp-like environment.

In profile Mi.3, the lower part of Unit 4b (thin section 841), contains more clay than the same unit in previous profile Mi.6. The fabric of the light gray clay is again unistrial, in which silt, fine and medium sand grains, up to a maximum of 300 μm in diameter, and occasionally lithorelicts of quartzite, are embedded in a porphyric arrangement. In an upward direction (thin section 840) the clay content decreases suddenly, and the s-matrix is mainly composed of silt and sand grains, commonly up to 500 μm in diameter, with little weak unistrial clay in between, forming a dense porphyric arrangement. Only very few fine to coarse sand-sized (up to 650 μm in diameter) quartzites occur. Additionally, micro depressions are observed with an infilling consisting of well-sorted laminae of: clay, or clay mixed with very fine silt, or very fine silt grains (less than 10 μm in diameter) or fine silt (less than 30 μm in diameter). The thickness of the individual laminae does not exceed 500 μm. Remnants of layers, consisting of unsorted silt, 600 μm thick, are also found.

The change from clayey to coarser deposits, with depression infillings of laminated fine material, suggest an alternation from a relative calm backswamp-like environment to a more intermitted environment. In the last-mentioned environment, sedimentation occurred of unsorted coarser material in shallow water, and erosion with formation of depressions on the one hand, and on the other hand giving rise to the formation of well-sorted thin laminae, possibly deposited by overland flow or by meltwater with a laminar flow and without simultaneous raindrop impact.

More to the west, at site Mi.5, in the vicinity of profile Mi.3, Unit 4 is calcareous, e.g. Unit 4c.

Three mammoth-sized thin sections (nrs. 848-850) were taken in this unit, showing from bottom to top:

- a layer of nearly 3 cm thick micro-cristalline carbonate material (micrite) in which silt, very fine and fine sand grains (up to 130 μm in diameter) are embedded in a porphyric arrangement. Additionally very few Bt-nodules (diameter 2 mm) are observed, e.g. pedorelicts of an older soil horizon, and shell fragments.
- an almost non-calcareous layer, 2 cm thick, consisting of gray unistrial clay in which is embedded some silt, very fine and fine sand grains (up to 150 μm in diameter), and shell fragments. In this, locally very thin (300-500 μm) unistrial clay laminae oc-

cur parallel with the surface. The boundary with the lower micrite deposit is gradual.

- a 5 to 7 cm thick layer of laminated fine sand (up tot 350 μm in diameter), loosely packed and with very few silt-sized grains enclosed. Only the packing voids in the top of this layer are partly filled with micrite, showing an agglomeroplasmic crystic fabric. The boundary with the horizon below is sharp.
- the almost 4 cm thick top layer, which resembles the bottom layer, consists of micrite, in which are embedded silt, very fine and fine sand grains, and many shell fragments, oriented parallel to the surface. This deposit is locally free of carbonates, showing an almost pure argillaceous matrix of which the original sedimentary unistrial fabric has been completely changed by soil formation, giving rise to an omnisepic plasmic fabric. Few thin, non-calcareous laminae are enclosed, parallel with the surface, consisting of silt, very fine and fine sand grains, less than 200 μm in diameter. The shell fragments occur with their convex side in upward as well as in downward direction. The boundary with the horizon below is sharp.

The unistrial fabric of the argillaceous deposit and the enclosed laminae, parallel to the surface, of fine sand and clay, could be formed in a backswamp-like environment. The clay content is masked in the microscope by micrite, except for the carbonate-free locations, where almost pure clay is observed.

The occurrence of micrite mainly in the argillaceous layers and only in depressional positions, suggests a post-sedimentary accumulation of carbonates, determined by the hydrological paleoregime, and giving rise to the formation of calcareous tufa, e.g. Unit 4c, in the first unstable cycle (K1u). Calcareous tufa is a less compact, more impure and porous variety of travertine (Fairbridge and Bourgeois, 1978, p. 819).

The presence of molluscs and other faunal remains (see van Kolfschoten, 1985 and Meijer, 1985) in this unit strongly suggests that the accumulation of carbonates must have taken place shortly after primary sedimentation and before the soil formation in the K1s-cycle. Due to the local carbonate-rich environment the fossils survived dissolution by soil formation, resulting in a zone of fossil finds no. 2.

Soil formation in Units 4b and 4c in the K1s-cycle

Soil formation in the first stable cycle in Units 4b and 4c of profiles Mi.6, Mi.3 and at location Mi.5 is very similar, showing the following pedological features:

- Biological activity with the formation of biopores (most common in Unit 4b of profile Mi.3), matric fecal pellets (only observed in Mi.3), and pedotubules (only in Mi.3).
- Reorientations of the clay minerals in the gray, reduced, argillaceous groundmass, resulting in vosepic (near cracks), masepic and skelsepic plasmic fabrics (around skeleton grains) in profiles Mi.6 and Mi.3. In thin section 904 the plasma reorientations are locally rounded features. At location Mi.5 the gray argillaceous groundmass has largely retained its primary unistrial sedimentary fabric, and shows only in local decalcified spots an omnisepic plasmic fabric.
- Light gray illuviation argillans occur only in profile Mi.6 (thin section 904).
- Brown and redbrown illuviation ferriargillans and matriargillans are incidentally observed in Mi.6 (thin section 904), common in Mi.3 (thin sections 841 and 840) and not at location Mi.5. If these ferriargillans are found in combination with the gray argillans, they occur closest to the remaining void.
- Accumulations of oxides and hydroxides of iron occur as ferrans in the voids and as neoferrans near the voids in the groundmass of Mi.6, Mi.3 and site Mi.5. At the two last-mentioned sites some ferrans are acicular in a radial fabric, which could be an indication of the mineral goethite.
- Sesquioxidic and manganiferous rounded or irregular nodules, and combinations of it, occur in both Units 4b and 4c. The manganiferous type is mainly observed in profile Mi.3.
- Brown argillaceous papules occur in Mi.6, but mainly in Mi.3.
- Carbonate solution phenomena followed by re-accumulation, as calcitans and neocalcitans, are only observed in Unit 4c at site Mi.5.

Soil formation during the first stable cycle in Unit 4b in profile Mi.6 (thin section 904) shows little biological activity, reduction of the largest part of the groundmass, with clay illuviation in an anaerobic environment (gray argillans), locally iron and manganese segregation by oxidation, giving rise to formation of ferric and manganiferous nodules and (neo)ferrans. Based on these hydromorphic phenomena, in combination with grayish clay illuviation, this horizon is classified as a B3tg horizon, formed in a mainly wet environment. The B3tg together with the Cg horizon in the lower Unit 4a, are possibly the remnants of a heavily truncated (during the following unstable phase) Gleyic Luvisol palaeosol, developed under a deciduous forest cover in a temperate climate. In the absence of an A horizon and of the main part of the B horizon, this classification can only be tentative.

The brown and redbrown illuviation phenomena (ferriargillans and matriargillans) associated with aerobic conditions, are regarded as pedological features from a more recent stable phase (K3s). The resemblance with the pedological features in the overlying Unit 5.2, and their occurrence at the grayish argillans, is in agreement with this interpretation.

The vosepic reorientations in the argillaceous groundmass along cracks are due to stress-induced deformations by swelling of the groundmass, along these cracks. The more or less rounded plasma reorientations and the formation of papules could be the result of cryogenic processes (cryoturbation) in a more recent unstable phase after the K3s-cycle. The indications for this type of process are however very weak. The papules could also be the result of swelling and shrinkage movements or of bioturbations in the soil.

Although the top of this truncated palaeosol is situated in the zone of finds of site C (Roebroeks, 1985), no indications are found for human activity.

The soil formation during the K1s-cycle in Unit 4b in profil Mi.3 (thin sections 841 and 840) is still weaker than in the previous profile Mi.6, showing mainly hydromorphic phenomena without clay illuviation under anaerobic conditions. Consequently this unit is classified pedologically as a Cg horizon. The brown illuviation features are the result of soil formation in the more recent K2s and, possibly, K3s-cycles. Indications for frost-induced phenomena are in this polygenetic horizon slightly stronger. These are: besides the formation of papules, locally developed platy structure (with in the planar voids brown illuviation argillans) and laminae bending in upward direction, probably caused by injection features (see Coutard and Mücher, 1985).

The soil formation during the K1s-cycle in Unit 4c at site Mi.5 (thin sections 848-850) is almost identical with Mi.3 in Unit 4b, showing hydromorphic phenomena and biological activity, and is consequently classified as a Cg horizon. Additionally this horizon is partly decalcified in the K1s-cycle. The possible goethite ferrans at this site and in profile Mi.3 are regarded more as a time-depending formation than as a climatologically determined phenomenon. It is likely that the heavily truncated paleosols, showing only a Cg horizon in Mi.3 and Mi.5, correspond with the eroded paleosol in Mi.6 in Units 4a and 4b in comparable position, and therefore remnants are of a Gleyic Luvisol.

Indications for human activity are not found in Mi.3 and Mi.5.

Unit 5: 'Loams'

Unit 5.1

In the micromorphologically analysed profiles Unit 5.1 is only recognized in the field in profile Mi.6 (Fig. 3) and additionally during the micromorphological analyses in profile Mi.3 (Fig. 4) in thin section 839.

Sedimentation in the K2u-cycle

The second unstable cycle started with a strong erosional phase, truncating the soils of the first stable cycle, followed by sedimentation.

The lower part, thin section 905, of Unit 5.1 in profile Mi.6 consists of light gray unistrial argillaceous groundmass in which are embedded dominantly silt and very fine sand grains, and less fine sand, and only incidentally medium sand grains (maximum diameter of 350 μm) in a porphyric arrangement. Only very few shale and quartzite fragments are observed with a diameter between 100 and 250 μm.

The sediment is coarsely laminated and inclined, at an angle of 35-40° to the horizontal. Occasionally in the sediment almost pure thin (50-100 μm thick) clay laminae occur with a strong unistrial fabric. Pure sand laminae hardly occur. Various laminae, with a maximum thickness of 5 mm, are more pronounced by the presence of sharply bounded, rounded, reddish brown ferric nodules with a diameter up to 500 μm. The void pattern is characterized by fine meso to fine macro (80-1000 μm) craze planes in directions normal and subparallel to the tilted lamination.

The upper part of Unit 5.1 in profile Mi.6, thin section 906, is more sandy, contains less clay and silt-sized particles than the lower part, and exhibits no lamination.

Unit 5.1 in profile Mi.3 is only recognized in the lower part of thin section 839. The 4 cm thick deposit shows a disturbed coarse lamination. Remnants still occur of wavy, horizontal layers of: unsorted silt (1 mm thick), unistrial clay with fine silt (150-1000 μm thick), and almost pure unistrial clay (50-700 μm thick). In between the laminae are yellow to light brown, (sub)angular soil nodules (probably eroded from a relatively nearby Bt horizon), ranging in size from medium sand to gravel size (2.5 mm in diameter). They show a porphyric arrangement with an omnisepic plasmic fabric. Common medium sand to gravel-sized (up to 3.4 mm) lithorelicts are observed, e.g. quartzite, siltstone and shale fragments.

The parallel lamination in the bulk of this Unit 5.1 showing an alternation of coarse material (soil nodules and lithorelicts up to gravel size) with fine material (laminae of silt, clay with silt, and clay) is attributed to an intermittent regime of intermediate shallow fluvial flow or sheet flow (rainwash and afterflow). The unlaminated upper part of Unit 5.1 in profile Mi.6 could be attributed to deposition by rainsplash. The soil nodules and the ferric nodules are probably locally derived, transported remnants of a Bt horizon, formed in an earlier stable phase. Tilting of lamination and formation of wavy laminae could be the result of deformations by cryoturbation after deposition.

Soil formation in the K2s-cycle

Unit 5.1 of profile Mi.3 (Fig. 4) shows only little soil formation from the second stable phase, consisting of very little biological activity (biopores and pedotubules), plasma reorientations as skel-, ma- and omnisepic plasmic fabrics, and medium to thick, dirty brown speckled, continuous illuviation ferriargillans. This type of argillan and pedotubule also occur in the lower Unit 4b, but not in the overlying Unit 5.2. The presence of the clear renewed lamination in Unit 5.1. in combination with another type of illuviation phenomena is in support of another second cycle with sedimentation and soil formation, and not of a continuation of the first cycle.

The yellow illuviation ferriargillans and matriargillans in this unit are identical with those in the overlying horizon, and are consequently regarded as pedological phenomena from a more recent stable phase (K3s).

This soil is so thin and weakly developed that it is no longer possible to determine whether it is the remnant of a weakly truncated incipient soil, or of a strongly truncated well-developed Luvisol. In Figure 4, the erosion of Unit 5.1 is evidenced by the presence of a gravel layer.

Soil formation in Unit 5.1 of profile Mi.6 mainly caused few gray illuviation argillans in the beginning (thin section 905), followed by light brown illuviation ferriargillans (thin section 905). The argillans are dominantly observed as infillings in the inclined planar voids. A large part of these cutans are subsequently broken down into papules. The amount of argillans increases in upward direction filling almost completely all voids (thin section 906).

This illuviation horizon is interpreted as a B3t horizon, which continues in upward direction in Unit 5.2, and will be discussed later. Consequently, this Bt formation is regarded as belonging to the third stable phase (K3s) and not to the second one (K2s).

Although the top of Unit 5.1 in profile Mi.3 (thin section 839) is situated on the zone of finds no. 3 (Roebroeks, 1985) no indications are found for human activity.

Unit 5.2.

Unit 5.2. was studied in profiles Mi.2 (Fig. 2), Mi.3 (Fig. 4) and mainly in profile Mi.4 (Fig. 4). During the third unstable phase (K3u) the soils developed in the K1s and K2s cycles are firstly heavily truncated and secondly buried by deposition of Unit 5.2. Subsequently soil formation occurred in the stable phase (K3s).

Sedimentation in the K3u-cycle

In the top of thin section 753 in profile Mi.2 (Fig. 2) the boundary between Unit 4a and 5.2 occurs. The erosion of the palaeosol of the K1s-cycle is followed by deposition of the gravel layer. Immediately above the erosion level one chert fragment of 1 x 2.9 mm occurs, covered by a 700 μm thick silt capping, consisting mainly of silt and minor proportions of clay and very fine sand grains.

Unit 5.2 in profile Mi.2 (Fig. 2) consists of poorly sorted material: mainly silt, common very fine and fine sand, and little medium sand-sized grains with a maximum diameter of 300 μm, some lithorelicts, as quartzites and sandstone fragments (maximum diameter: 600 μm), and occasionally fragments of mud crusts with a weak unistrial fabric (only observed in thin section 755). In between the closely packed skeleton grains brown fine clayey material is found, giving rise to an intertextic related distribution pattern. Locally the skeleton grains occur in a granular arrangement, without clay in between the grains. The difference between the lower and upper parts of the profile (thin sections 754 and 755) is restricted to an increase in the silt-sized particles in an upward direction and to the appearance of subrounded soil nodules (above 54.28 m + N.A.P.), ranging in size from 200 to 2100 μm, composed of material which is almost identical with that of the matrix of the profile itself.

Unit 5.2 in profile Mi.3 (upper part of thin section 839) is very similar in composition: mainly silt with sand-sized particles up to 600 μm in diameter (coarse sand) and very few lithorelicts (shale, silt- and sandstone fragments) with a maximum diameter of 0.5 mm. Divergent from the previous profile Mi.2, the deposit is slightly horizontally laminated and the argillaceous material in between the skeleton grains shows a weak unistrial fabric parallel with the lamination.

Unit 5.2. in profile Mi.4 has a composition similar to the previously mentioned profiles. The unit consists mainly of silt and less very fine and fine sand, and little medium sand-sized grains up to 400 μm in diameter. In between these skeleton grains brown clay occurs in an intertextic to close porphyric arrangement. This clayey groundmass exhibits mainly in the lowest part of Unit 5.2 an unistrial fabric, which disappears gradually in upward direction. Lithorelicts, as fragments of quartzite, shale, silt- and sandstone, are observed throughout the unit. The coarsest lithorelicts occur however in the lowest part (thin section 847), with a diameter up to 1.3 mm. In common they are not larger than 0.5 mm. In the last-mentioned thin section there is an inclined fissure, 1.5 cm wide, with an infilling of silt and fine sand. Near the rims the infilling is laminated parallel to the fissure walls, consisting of silt, or very fine sand or thin unistrial argillaceous laminae.

Occasionally in Unit 5.2 are observed: thin horizontal layers of fine sand (thin sections 846 and 845), layers (150 μm thick) of unsorted silt (thin section 844) and layers of silt enriched with opaque grains (thin section 843). Fragments of mud crusts and of clay laminae occur in thin section 846.

Clear indications for specific environmental conditions during the formation of Unit 5.2. are not found. The unistrial fabric, the poorly sorted grainsize composition and the locally observed laminae could indicate a fluvial deposition in shallow water (with in upward direction decreasing energy of flow), alternating with short periods of non-deposition (formation of mud crusts) or periods with overland flow, with the formation of rainwash deposits.

The well-laminated fissure infilling in the lowermost part of this unit suggests a filling-up of an incipient frost crack by meltwater.

Soil formation in the K3s-cycle

Soil formation in profile Mi.2 (thin sections 754 and 755) is characterized by biological activity, clay illuviation and hydromorphic features, with the formation of ferric and manganiferous nodules, and neoferrans around voids.

Soil formation in Unit 5.2 in the upper part of thin section 839 of profile Mi.3 shows the same characteristics: clay illuviation, ferric nodules, neoferrans, and additionally accumulations of ferrans in the voids. The hydromorphic features contrast with the former soil features of the K2s-cycle, being red brown in colour, and not dark brown or black.

Soil formation in the same unit in profile Mi.4 shows the following characteristics:

- Biological activity with biopores, pedotubules and fecal pellets, increasing in upward direction, and developed most strongly in thin section 843 and higher in the profile.
- Clay illuviation, showing several types of illuviation cutans such as yellow and brown illuviation ferriargillans, dirty brown speckled ferriargillans and matriargillans. They appear still faint in the lower part of the profile (thin section 847), distinct in thin sections 846 to 844, and decrease again gradually in upward direction (thin sections 844 to 842).
- Hydromorphic phenomena occur mainly in the lower part of the profile, decreasing upwards, such as: ferric nodules, ferrans and neoferrans.
- Accumulations of carbonates, although in very small quantities, are observed, starting from thin section 846 in upward direction, in the whole of the profile. They occur mainly as carbonate nodules and sometimes as calcitans, for example in thin section 843.

The faint illuviation horizons in Mi.2 (Fig. 2; thin sections 754 and 755) and Mi.3 (Fig. 4; upper part of thin section 839) are interpreted as B3t horizon formations of the K3s-cycle. In this same cycle, in profile Mi.4 (Fig. 4; largely based on the distinct clay illuviation in thin sections 846 to 844, but, less distinct above and below in the profile) a B3t (thin section 847), a B2t (thin sections 846-844) and a B1t horizon (thin sections 844-842) have developed.

The strong truncation of profiles Mi.2 and Mi.3, and moderate truncation of Mi.4 is attributed to an erosional phase in a following unstable cycle.

The accumulations of carbonates in profile Mi.4 (presumably calcite), based on their position in the profile, are regarded as formations in a more recent K-cycle, due to dissolution of carbonates from the surmounting calcareous Middle Silt Loam (Unit 6).

The buried truncated paleosol remnants in the profiles Mi.2, Mi.3 and Mi.4, of the third stable phase (K3s), largely based on the presence of an argillic horizon, initially with impeded drainage, showing however no reduction phenomena, and later on well-drained, is classified as a Luvisol, formed under deciduous forest in a temperate climate. In the absence of an A horizon this classification can only be tentative.

Indications for human activity are very limited, although at the base of Unit 5.2 in profile Mi.2 artefacts are found (Sites A and D; see Roebroeks, 1985. Only the angular chert fragment at the erosional surface of Unit 4a (thin section 753) could be an artefact.

At location Mi.1, a thin section was made of a sediment initially considered to be the top of Unit 5.2, which showed a large resemblance with the Luvisol from the K3s-cycle, but in sloping position. Investigation of thin section 633 revealed: firstly, a micro lamination, and secondly, that the individual laminae are composed of rounded soil nodules with varying diameter, derived from various soil horizons of a Luvisol. This suggests that the top layer has been formed by overland flow during rainfall (rainwash), derived from a Luvisol of presumably the K3s-cycle.

More upwards at the same location Mi.1, Unit 6.3 was sampled: a calcareous laminated silt loam with locally enclosed very thin black laminae, less than 3 mm thick. The black laminae showed in the field a large resemblance with the Eltville Tuff Layers as observed already in many other loess exposures in southern Limburg, Belgium and West Germany (see among others: Meijs et al., 1983). To examine this possibility, thin section 634 was made. Analysis of this thin section shows that:

- The black layers are composed of fine calcareous silt enriched with opaque minerals and anisotropic heavy minerals, without volcanic ones as occur in the Eltville Tuff Layers.
- In between the black laminae thin layers (0.4 to 8.4 mm thick) are observed of fine silt (smaller than 30 μm in diameter), or of very fine silt (smaller than 10 μm in diameter), and incidentally of unsorted silt (10-50 μm), or of silt with very fine and fine sand (less than 200 μm in diameter), and sporadically with aggregates, smaller than 250 μm in diameter.

Up until now no tephra layers have been found in the Belvédère pit. Compared with experimental results (Mücher and De Ploey, 1977; Mücher et al., 1981; Mücher and De Ploey, 1984) the above described laminae of Unit 6.3 could be formed as a result of deposition by afterflow, without simultaneous raindrop impact, or by meltwater flow.

CONCLUSIONS

The various features described and discussed in the foregoing units may be ordered in time as follows:

- During K1u-cycle formation of Unit 4a largely by fluvial action and less by afterflow or meltwater flow. In upward direction deposition by overland flow and rainsplash increases (profile Mi.2). In the topographical lower parts (profile Mi.6) this unit is formed in a backswamp-like environment, just as the Units 4b (Mi.3 and Mi.6) and 4c (Mi.5). In the last-mentioned unit post-sedimentary accumulation of carbonates followed, giving rise to the formation of calcareous tufa.
- Soil formation during K1s-cycle resulted in the formation of a well-drained Luvisol in Unit 4a (Mi.2) in a relatively topographically higher position. In Units 4a (Mi.6), 4b (Mi.3 and Mi.6) and 4c (Mi.5), all in lower position, dominantly remnants are found of a Gleyic Luvisol, developed in a mainly wet environment.
- In the K2u-cycle erosion of the soils formed in the K1s-cycle and deposition of Unit 5.1 (Mi.3 and Mi.6) in an alternating regime of shallow intermittent fluvial flow on the one hand, and on the other hand of sheet flow (rainwash and afterflow) and deposition by rainsplash.
- From the soil formation in the K2s-cycle in Unit 5.1 only few remnants are found (Mi.3). They could be an indication for a weakly truncated incipient soil formation or of a strongly truncated well-developed Luvisol.
- In the K3u-cycle erosion of the soils formed in the K1s and/or K2s-cycle, followed by water-laid deposition of Unit 5.2 (profiles Mi.2, Mi.3 and Mi.4). The sedimentation occurred mainly in shallow water alternating with short periods of non-deposition, or periods of overland flow resulting in the formation of rainwash deposits. Although Unit 5.2 in the field shows a large resemblance (caused by its homogeneous silty structure over a large area, about 2 ha) with the loess deposits of pre-Weichselian age in other exposures in southern Limburg, it is explicitly not regarded as such. This is mainly based on the sedimentary structure and composition of the deposit in thin section which do not correspond with those of loess. However, it cannot be excluded that the silt fraction is partly or largely derived from a loess deposit, subsequently reworked and mixed with terrace materials during redeposition (see also Meijs, 1985).
- Soil formation in the K3s-cycle in Unit 5.2 (profiles Mi.2, Mi.3 and Mi.4) giving rise to the formation of a well-drained argillic horizon, showing only initially phenomena of impeded drainage, which could indicate a truncated buried Luvisol palaeosol.

Luvisols, classified in The Netherlands as 'radebrikgronden' (de Bakker, & Schelling, 1966) and in West Germany as 'Parabraunerden' (Mückenhausen, 1962), can be formed under deciduous forest in a temperate climate. According to Blum and Ganssen (1972) are Köppen's Cf-climates favourable for the formation of argillic horizons. FitzPatrick (1971) describes the environmental conditions for this formation in terms of a moist to wet climate with a dry season.

The archaeological site C occurring in Unit 4, deposited during the first unstable cycle (K1u), is according to the paleontological assessment of the faunal assemblage (See van Kolfschoten, 1985 and Meijer, 1985) formed during a relatively warm temperate climate. However, thin section analysis revealed no indications for specific climatic conditions.

Well-preserved locations of archaeological finds are recognized in sediments deposited in unstable periods, whereas translocated artefacts are mainly observed in the beginning of Ku-cycles (see Roebroeks, 1985). In this respect, the in situ finds in the lowest part of Unit 5.2 in profile Mi.2, formed in the beginning of K3u-cycle, are an exception. In fact, this is the only location where indications for human activity have been observed in thin sections. The foregoing suggests that short-term human occupation at the Belvédère site is only documented in unstable phases.

ACKNOWLEDGEMENTS

The author is very much obliged to Dr. A. C. Imeson for his stimulating criticism and suggestions for improvement. Thanks are also due to Mr. J. Nederlof (Institute of Prehistory, Leiden University), and Mr. C. J. Snabilié for making the drawings, Mrs. M. C. G. Keijzer-v.d. Lubbe for typing the manuscript and Mr. C. Zeegers for preparing the thin sections.

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LOESS STRATIGRAPHICAL RESEARCH AT THE PALAEOLITHIC SITE MAASTRICHT-BELVÉDÈRE

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CONTENTS

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ABSTRACT

Four representative loess sections in the Belvédère pit were investigated on their mineralogical content in the loess fraction (30-63 µm). Only lithostratigraphical units, containing real loess, were incorporated in this research. By means of the percentage of green amphibole (in fraction 30-63 µm) the lithostratigraphical Units 5 and 6 could be placed in a loess stratigraphical model, Unit 6 being deposited in the Weichselian, Unit 5 in the Saalian loess cycle.

INTRODUCTION

Until now the loess deposits of The Netherlands could only stratigraphically be divided into a Weichselian (Formation of Twente) and a pre-Weichselian part (Formation of Drenthe). Since a short time it has been tried to precise this rough division by means of new research methods. In 1980 for instance the traditional stratigraphical model had to be changed according to new findings of macro- and microscopic tephrostratigraphical research (Meijs, 1980, Meijs et al., 1983). Besides this, mineralogical research of the loess fraction brought new perspectives for a more detailed loess stratigraphy (Mees and Meijs, 1984).

For the palaeolithic site Maastricht-Belvédère the latter kind of research was used to obtain a loess stratigraphical framework.

The investigation of the mineralogical composition of the grainsize fraction 30-63 µm of loess samples started in France, Belgium and Germany by Lautridou and Juvigné. They found that Weichselian loess contained a greater percentage of amphibole than pre-Weichselian loess (Lautridou, 1968; Juvigné, 1978; Thieme et al., 1981). The research of Mees and Meijs (1984) revealed that this was also the case in the loess deposits of The Netherlands. On the basis of recent mineralogical research of major loess profiles of The Netherlands it was found that also the pre-Weichselian loess deposits could stratigraphically be divided by means of this method (see figure 1).

In loess sections, containing several interglacial palaeosols, each packet of loess lying between two interglacial soil-formation periods seemed to have a rather uniform percentage of green amphibole. The older the loess the lower that percentage. In calling the loess packet between two interglacial soil-formation periods a loess cycle, the following loess stratigraphical model could be composed.

	green amphibole (30-63 µm)
Holocene soil	
LOESS CYCLE I (Weichselian)	6.5 - 35 %
Interglacial paleosol A (Eemian)	
LOESS CYCLE II (Saalian)	3 - 6.5%
Interglacial paleosol B	
LOESS CYCLE III	1.5 - 3 %
Interglacial paleosol C	
LOESS CYCLE IV	0.7 - 1.5%
Interglacial paleosol D	
LOESS CYCLE V	0 - 0.7%

Grouping of the green amphibole percentages in the different Weichselian lithostratigraphical units justified the following subdivision of loess cycle I.

PLENIGLACIAL B Horizon of Nagelbeek (Interstadial paleosol)* PLENIGLACIAL A	10 - 35%
EARLY WEICHSELIAN	6,5 - 10%

* According to Haesaerts et al. (1981) the tundragley palaeosol, called Horizon of Nagelbeek is dated around 22.000 years BP.

A condition for this type of research is that the samples should consist of real loess. In solifluted and washed loess samples the possibility of contamination with underlying material is to great.

METHODS

The heavy and light minerals were seperated by means of a centrifuge. The heavy mineral fraction was sucked up with a micropipet. From each sample 200-300 transparent heavy minerals were counted according to the ribbon-counting method, as described by Van Harten (1965).

RESULTS

In the Belvédère pit four loess sections (including those at the archeological sites B and E) have been examined on their mineralogical content in the loess fraction (30-63 µm) (see figure 1). In comparing the green amphibole values with those of the above mentioned loess stratigraphical model the following conclusions can be made.

The lithostratigraphical Units 6 and 7 belong to loess cycle I and Unit 5.2 to loess cycle II. The Units 1, 2, 3, 4 and 5.1 are all of non-aeolian origin and so cannot be incorporated in the loess stratigraphical research.

Although material of Unit 6.2 consists of solifluted and washed sediment, it still has been investigated on its mineralogical composition in the loess fraction. This because of its archeological and paleontological importance. The green amphibole percentage of this unit ranges from 7 to 21%. The reason for this can be contamination with the older underlying sediment material. So it is more probable Unit 6.2 was deposited in Pleniglacial A than in the Early Weichselian.

According to the green amphibole values Unit 6.1, 6.3 and 6.4 belong respectively to the Early Weichselian, Pleniglacial A and Pleniglacial B periods.

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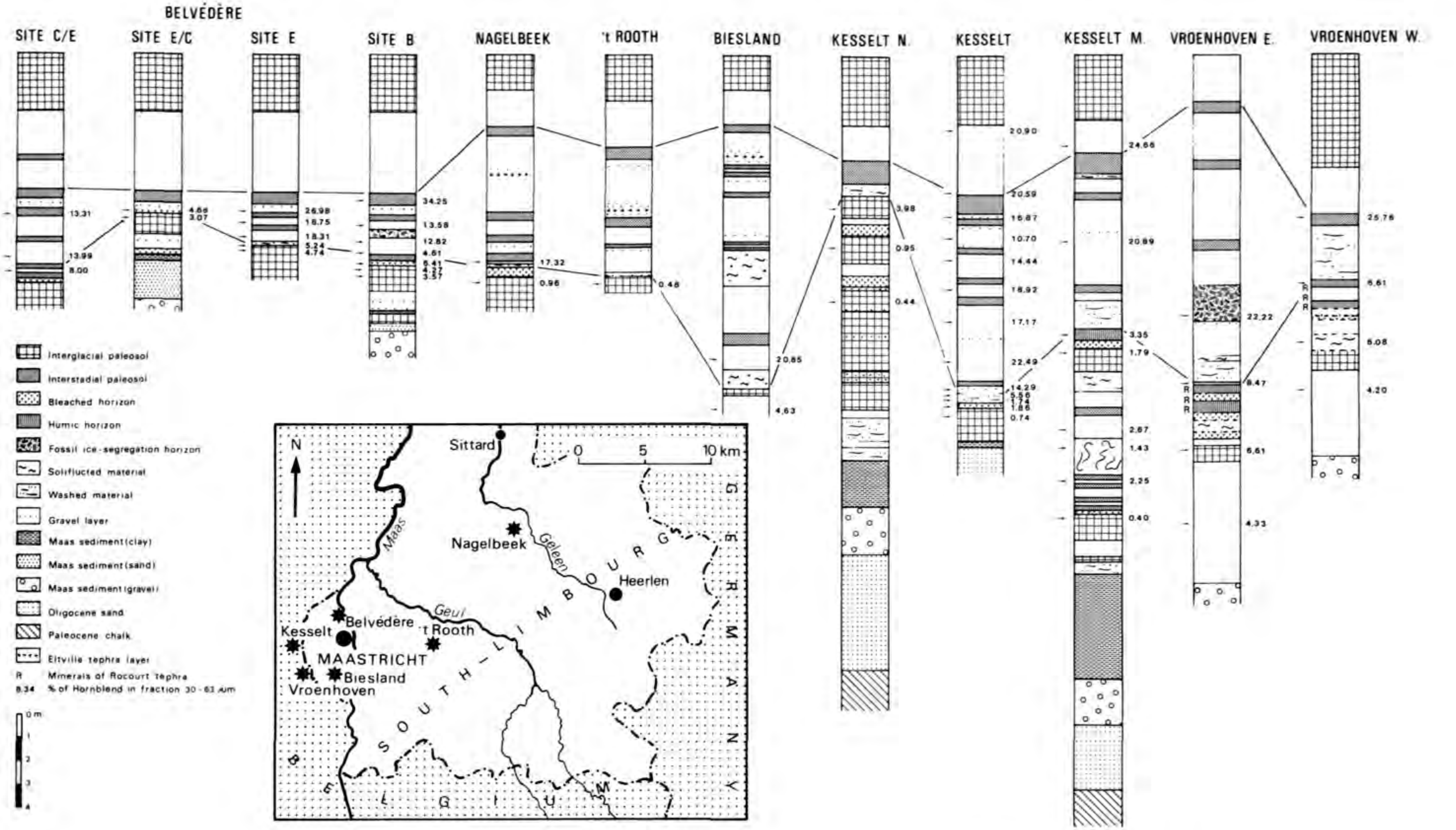

Fig. 1. Mineralogical investigation of the major Dutch loess profiles. On the right side of the profiles the percentages of green hornblend (amphibole) in the loess fraction of the samples are indicated.

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SOLUTION SLOTS OR ICE-WEDGE CASTS?

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CONTENTS

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ABSTRACT

Several types of wedge-shaped and graben-like deformations in loams and terrace deposits at Maastricht-Belvédère show some striking similarities with ice-wedge casts. Normal faulting, vertically dressed pebbles and infilling by flow and downfall are characteristic. Comparison with a typical ice-wedge cast from the same region stresses the absence of a vertically laminated central part in the deformation structures at Maastricht-Belvédère. It is concluded that wedge-shaped and graben-like features at Belvédère are caused by slot solution in the underlying chalk subsoil.

INTRODUCTION

Wedge-like downsinking structures are striking features on top of and in the Caberg terrace at Maastricht-Belvédère. They are piercing the terrace deposits and are filled with overlying loams. Their general form resembles ice-wedge casts. On the other hand circular hollows are frequently observed in the top of the terrace gravels and in the underlying coarse-grained Palaeocene chalk. The latter rock is very appropriate for dissolution and a karstic origin for the circular hollows is obvious. The interpretation of the deformation structures is important for the characterisation of the palaeoenvironment. In order to check the hypothesis of the deformations at Maastricht-Belvédère to be ice-wedge casts a comparison is made with typical ice-wedge casts formed in loess outside the chalk area.

DESCRIPTION OF THE DEFORMATION STRUCTURES IN THE TOP OF THE CABERG TERRACE AT MAASTRICHT-BELVÉDÈRE

Small graben-like or wedge-like forms occur frequently in the Belvédère pit at Maastricht. Their width varies from a few decimeters to several meters. The top of the disturbances is situated within the 'Loams' (Unit 5; see Vandenberghe et al., 1985). The deformation structures pierce through the 'loams' and fluvial sands (Unit 4) down into the terrace gravels (Unit 3). Whether they penetrate the underlying subsoil as well could not be observed.

In order to investigate the characteristics of the concerned structures three examples are described in detail.

In a first form (fig. 1) the wedge is sharply limited at the boundary with the surrounding fluvial sands. This limit is continuous and shows no interruptions by faulting. The wedge is filled with 'loams' which gradually and regularly have sunk downward. Movement is sometimes accompanied by downfaulting. The central part of the wedge consists of the uppermost part of disturbed sediments, in this case material derived from the B2t-horizon of the Rocourt-soil. The exterior part of the wedge is composed of dark-brown, clay-enriched 'loams' normally occurring below the Rocourt-soil. A smaller 'adventive' wedge also shows sharp boundaries and the same type of small normal fault at its southern edge marks the limit of the global sinking structure. The small edge may be explained as a tensional crack accompanying extension faulting. The upper part of frost fissures, which are posterior to the Rocourt-soil, have been moved towards the centre of the depression.

A second type of perturbation is a graben structure with similar characteristics but formed entirely in the terrace gravels (fig. 2). Its large width is caused by a series of extension faults. Although a step-like structure is obvious, the layering is almost continuous along the fault planes as well as in the centre of the structure.

A third kind of deformation is also formed within the terrace gravels. It shows vertical dressed stones at the edges (fig. 3). The vertical layering is due to infilling of the fissures along the fault planes. In the central part, however the orientation of the pebbles is random due to flow from the sides or horizontally directed due to vertical subsidence of cohesive blocks of the gravel unit.

Although apparently variable, the three kinds of perturbations show a few common characteristics. The central subsided part shows a complete absence of vertical lamination. Its original layering is conservated in the case of soil fall while homogenisation is due to processes of flow into a relatively wide depression. Secondly, the sides of the wedge are sharply limited by uninterrupted boundaries.

ICE-WEDGE CAST AT NAGELBEEK (Southern Limburg)

A nearby outcrop in thick loess deposits (Vreeken & Mücher 1981) allows the comparison with wedge forms of clearly periglacial origin. Within the Upper Silt Loams corresponding to Unit 7, ice-wedge casts are formed (Meijs et al. 1983). One of them is represented in fig. 4. Its upper part consists of a downward directed involution of more than 0.80 m (the original top was no more visible). The internal section of the lower part is composed of vertically laminated Upper Silt Loams. They are penetrating into the Middle Silt Loams (Unit 6) which are fractured by a series of extension faults. This zone of fracturing forms the exterior section of the lower part of the wedge. The depth of the lower part is about 2 m. The described subdivision in different parts and their respective structures are typical for ice-wedge casts (Vandenberghe, 1983a). Especially the vertical lamination in the centre of the lower part is a characteristic feature. It originates from the infilling by muddy sediments between the ice core and the wedge sides.

The ice-wedge has pierced the Eltville tuff layer and the greyish involuted Nagelbeek horizon. It is filled with Upper Silt Loam, while several meters of Upper Loess are covering the ice-wedge cast (Meys et al., 1983). It follows that, according to the age of the Eltville tuff (Semmel, 1967; Wintle & Brunnacker, 1983)

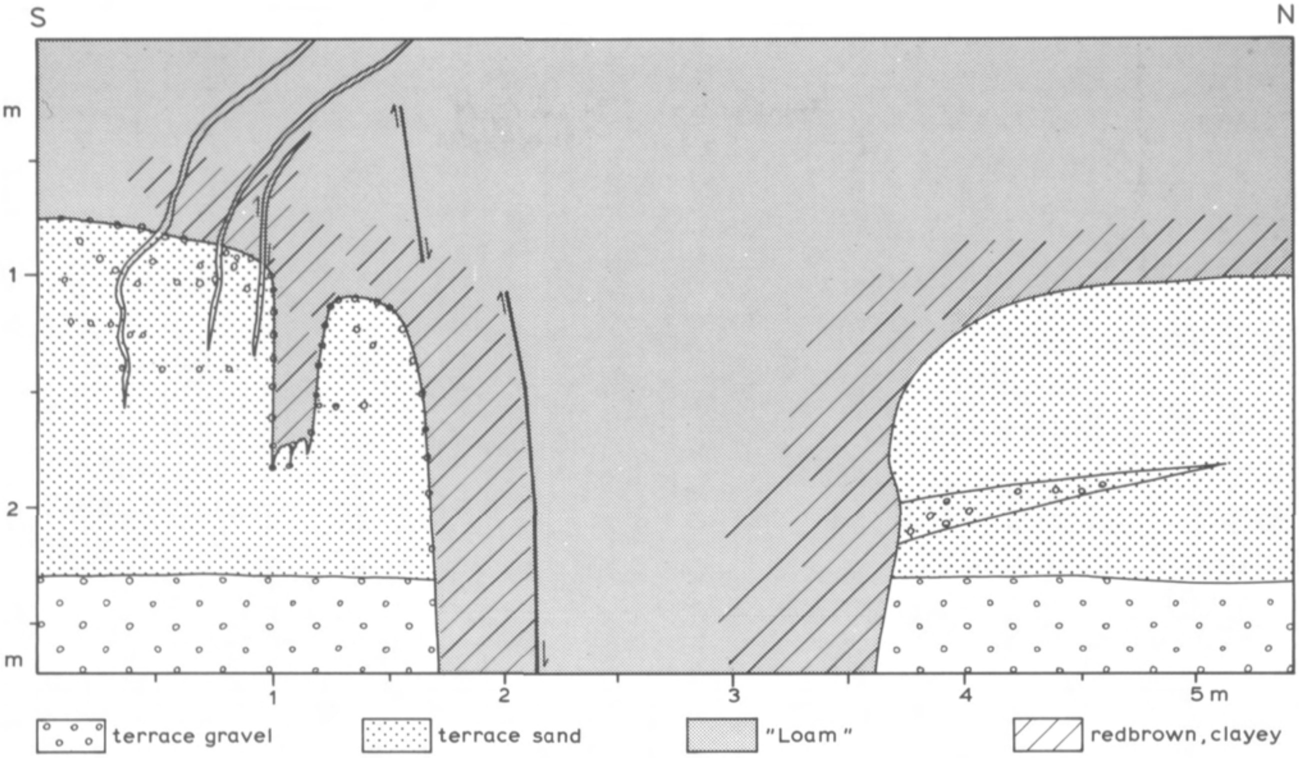

Fig. 1. Wedge-shaped structure within the 'loams' and terrace deposits (westside of the Belvédère-pit; top of the section is at ca 55 m + NAP).

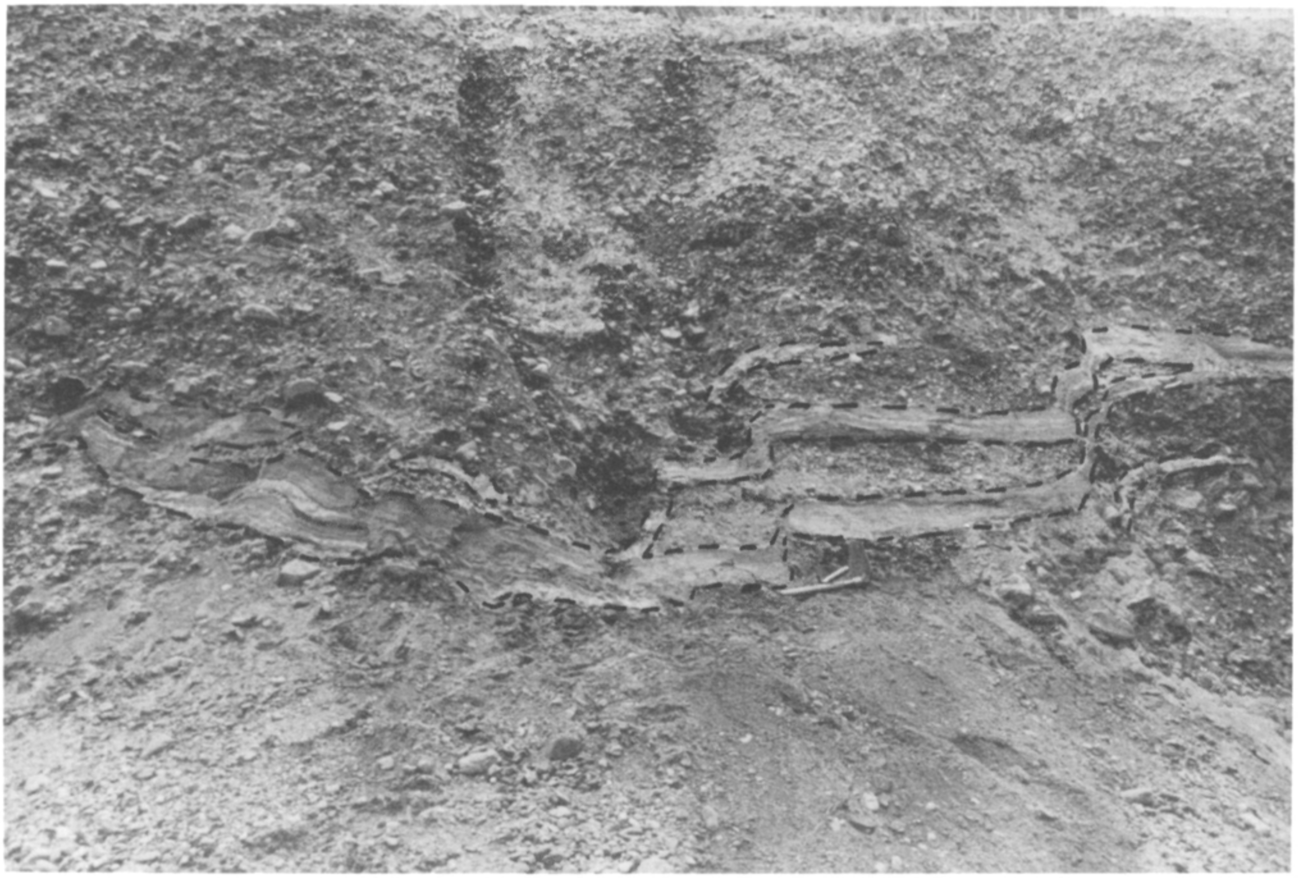

Fig. 2. Downfaulted deformation structure within the terrace gravels of the Caberg terrace (Belvédère-pit). The length of the shovel is 55 cm.

and the Kesselt soil B (Gullentops in Haesaerts et al., 1981; Gullentops, 1981) which is an equivalent of the Nagelbeek horizon, the ice wedge has been formed slightly after 21.000 yr B.P. The ice wedges at Nagelbeek correspond to the widely occurring level of ice wedges which have developed at that time (Vandenberghe, 1983b).

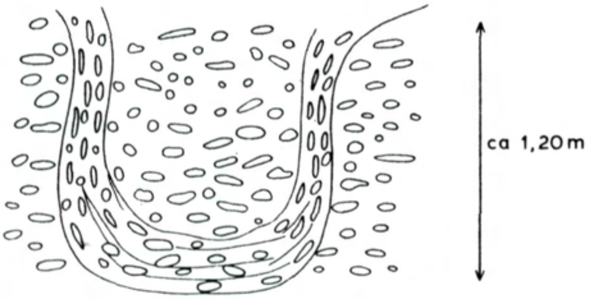

Fig. 3. Pocket-shaped downsunk structure within the terrace gravels of the Caberg terrace (Belvédère-pit).

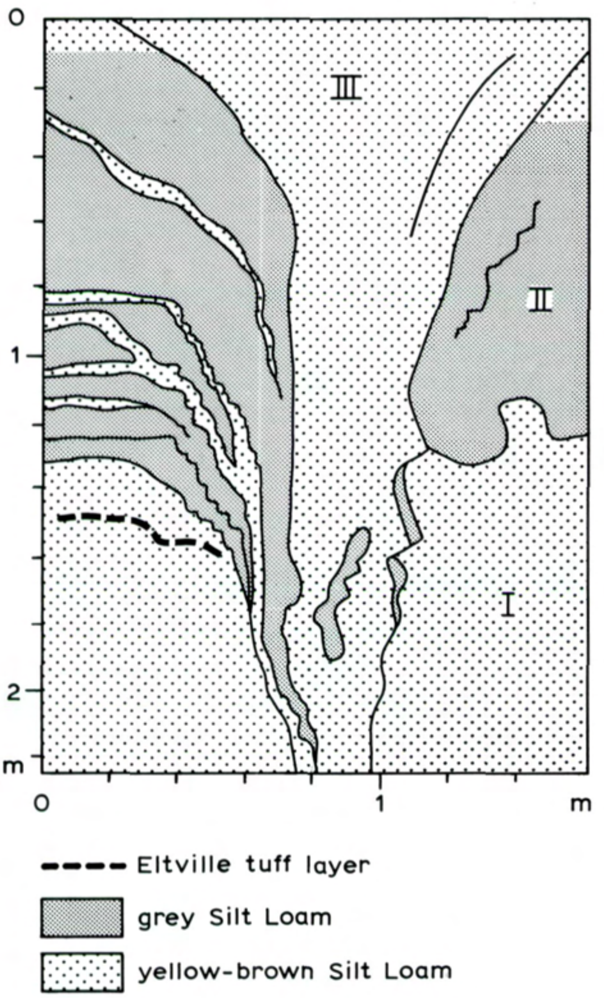

Fig. 4. Weichselian Upper Pleniglacial ice-wedge cast at Nagelbeek. I = Middle Silt Loam, II = Nagelbeek Horizon, III = Upper Silt Loam. The 0 m level is at ca 117 m + NAP; for situation see: Meijs et al. 1983.

COMPARISON OF THE SUBSIDENCE FEATURES AT BELVÉDÈRE WITH ICE-WEDGE CASTS

The deformation structures at Belvédère show some striking differences with ice-wedge casts:

a. The typical bipartition of the lower part of ice-wedge casts in a central and an exterior zone has never been found in the Belvédère subsidence features. The latter are characterized by sharp boundaries while locally present faults occur both near the edges and in the central part of the deformaion. In the ice-wedge casts, however, faulting is limited to the outer part. This results in transitional boundaries as is well illustrated at Nagelbeek (fig. 4).

b. The vertical lamination in the central lower part of ice-wedge casts is not always distinctly expressed in loess deposits. However, it is completely absent in the deformations at Belvédère. There the only vertical layering is present along the steeply faulted boundaries of some of these structures (fig. 3). Generally, the main part of the infilling is homogenized by slumping into the wedge-shaped openings. In other cases the total downsinking is effectuated by multiple faulting without any vertical layering in the centre of subsidence. Consequently the complete deformation (and not only the exterior part) takes the form of a graben.

Thus the subsidence features at Belvédère are filled by graben-like blockfaulting or by downslumping. The presence of tensional structures can easily be explained by any subsidence. They may show some similarity with ice-wedge casts (Black, 1983). Most remarkable is the complete absence of a central vertical layering which is, in the ice-wedge casts, caused by gradual melting of the ice cover accompanied by simultaneous infilling from the sides. The infilling by vertical fall as well as by flow from the sides obviously occurred in a short time over the total width of the cavity. Moreover, the deformations at Belvédère show a considerable heterogeneity of forms and of filling sediments. Finally they are unequally distributed over the area in contradiction with regularly developed ice-wedge polygons.

It may thus be concluded that the wedge forms on the Caberg terrace at Belvédère are no ice-wedge casts. By analogy to the circular hollows, which clearly have a karstic origin, the observed longitudinal wedge forms may be caused by solution of $CaCO_3$ along joints in the Palaeocene chalk. The observed karstic features are formed at several times between the end of the terrace formation and the formation of the Nagelbeek-horizon. Besides, favorable conditions for karstic processes were only present after lowering of the water table, it means from the incision of the Maas in the terrace gravels onwards.

CONCLUSIONS

In the Belvédère outcrop funnel-shaped sinks in the gravels of the Caberg terrace are obviously due to solution of the underlying Palaeocene chalk. On the other hand, wedge-shaped forms show at first glance some similarity with ice-wedge casts. Their internal structure, however, points to tensional cracking and filling by inflow from the sides. The characteristic vertical laminition of the lower central part of ice-wedge casts is completely absent in the deformations at Belvédère. Therefore the latter forms are interpreted as subsidence phenomena caused by slot solution of the joints in the chalk subsoil ('grikes'). The solution slots developed at different times during the deposition of the terrace sediments and overlying 'loams' up to the formation of the Nagelbeek horizon.

ACKNOWLEDGEMENTS

The author is grateful to Mr. W. M. Felder and Mr. H. Mücher for critically reading the manuscript, Messrs. H. Sion and C. van der Bliek took care of the drawings and photographic work.

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THERMOLUMINESCENCE DATING RESULTS FOR THE PALAEOLITHIC SITE MAASTRICHT-BELVÉDÈRE

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CONTENTS

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ABSTRACT

A brief review of the thermoluminescence technique as it applies to palaeolithic sites is presented and the thermoluminescence age for Unit 4 at Maastricht-Belvédère based on measurement of seven burned flints is reported: 270 ka (± 11, ± 22, Ox TL 712k).

INTRODUCTION

Thermoluminescence (TL) is a phenomenon exhibited to varying degrees by many minerals. Essentially it is the emission of light when a substance is heated, this light being additional to ordinary red-hot glow and usually occurring at a less elevated temperature. In so far as archaeological application is concerned the light is faint and a special high sensitivity photomultiplier is needed for measurement.

TL represents the release of energy that has been stored in the crystal lattice of the mineral, this energy being in the form of trapped electrons. These trapped electrons are the result of exposure to nuclear radiation and there is a weak flux of this from the radioelements (potassium-40, thorium and uranium) naturally present in minerals and soil. The basic notion of TL dating is that at the time of the event being dated the latent TL of the sample was effectively zero. Then during the millenia of burial the latent TL accumulated so that the TL observed from a sample to-day is a measure of age. The erasure of geologically acquired TL at the time of the archaeological event is an obvious essential for dating. In the case of burned flint it is the action of heat that achieves this, a temperature of around 400°C being needed. With sediment it is the action of sunlight in 'bleaching' the TL before deposition; windblown sediment such as loess will have a long exposure to sunlight while airborne and it appears that some types of waterborne sediment have been sufficiently exposed also.

The basic equation is:

$$\text{age} = \frac{\text{palaeodose}}{\text{annual radiation dose}}$$

The paleodose is evaluated from laboratory measurements of the archaeological accrued TL (the natural TL) and the sensitivity of the particular sample concerned, viz:

$$\text{palaeodose} = \frac{\text{natural TL}}{\text{TL per unit dose of nuclear radiation}}$$

Thus palaeodose represents the total dose that the sample must have received since the event being dated. Alternative terminology is equivalent dose (ED) and archaeological dose (AD).

The annual dose, or dose-rate, is determined by both laboratory and on-site measurements. It consists of two parts, the internal dose-rate from radioelements in the sample itself, and the external dose-rate from radioelements in the burial soil (up to a distance of about 25 cm from the sample). For flint the external component is often as much as 80% of annual dose and consequently the reliability of the age can be strongly dependent on an accurate evaluation of it. This component is alternatively called soil dose, environmental dose, gamma dose and gamma-plus-cosmic dose; the cosmic-ray contribution is typically about 20% of the external component, less in deep caves.

An important consideration in respect of the external components is the rapidity with which the sample became buried to a depth of 25 cm. Until that depth is reached it does not receive the full component; while lying on the surface uncovered it receives only half.

For on-site measurements we use (i) TL capsules and (ii) a portable gamma spectrometer. A TL capsule, usually of copper contains a highly sensitive TL powder and is buried in the soil in a situation that represents that of the sample as closely as possible; it is about 8 mm diameter and 40 mm long. Minimum burial time is a few months, a year being preferred; it is placed at the end of a 30 cm long auger hole. The detector of the gamma spectrometer is 65 mm in diameter so that a correspondingly larger hole is required; however in this case the measurement time is only half-an-hour.

The annual dose is influenced by the water content of sample and soil during antiquity. An upper limit to the effect is obtained by measuring the saturation content. The as-dug content can also be measured (using a tightly-tied plastic bag to avoid evaporation during transport to the laboratory): it is then a matter for discussion as to whether the average during burial was bigger or smaller than the as-dug value. Uncertainty about water content is one of the factors that limit the accuracy attainable and the collaboration of a soil scientist is important. For instance on this site our thanks are due to Burrough, Dirksen and Van der Westeringh from the Agricultural University of Wageningen for use of their detailed soil moisture analysis.

The maximum age that can be reached is dependent on the TL characteristics of the sample, its radioactivity, and the radioactivity of the soil. In round terms both flint and calcite can reach about half-a-million years, perhaps more; the limit for sediment is not yet established. The accuracy obtainable varies with circumstances, often being limited by uncertainty in water content. It is realistic to expect ±10% of the age; somewhat better can sometimes be achieved but it is unlikely that the error limits will ever be reduced below ±5% of the age. Although the accuracy is not high it is usually adequate for deciding in which of several possible isotope stages a site should be placed.

In respect of flint it is desirable to have several suitable samples from each context being dated, preferably half-a-dozen or more. The samples need to be well burned and large enough. They should not be exposed to sunlight or fluorescent light; they should be stored in the dark. The ultimate test of whether the burning is sufficient is an integral part of the TL measurement, the plateau test, and not all flints which seem to be well burned to the eye pass this test. The size requirement is a disc of flint roughly 3 cm x 1 cm. The flint is destroyed in the course of measurement.

Further information about application of TL dating to palaeolithic sites of NW Europe will be found in Aitken, Huxtable and Debenham (1985).

FLINT SAMPLES FROM MAASTRICHT-BELVÉDÈRE

These are all from the layer of fluviatile sediment containing the archaeological occupation, layer K in our nomenclature, which is Unit 4 as established by Vandenberghe et al., 1985.

Initial measurements began with a 'Maas egg' (Bv 161), for which the TL signal was in saturation, and a tiny scap of flint too small for routine analysis (Bv 1296). However the latter was large enough to confirm that the TL age was consistent with a date in excess of 200 ka. Further excavation produced a total of seven flints suitable for routine dating. Three of these were from the Site C area where we have gamma spectrometer and capsule measurements; they are K4 (Az-12/9), K5 (Cz-19/15) and K6 (Bz-20/2). K4 was from a less homogeneous part of the layer than the other two. We also have K11 (22/22-44) which was from a different part of the pit, Site F; a capsule measurement was made here.

K12 (dw 84/1) and K13 (dw 84/2) are from a manifestation of Layer K/Unit 4 about 25 m SE of the first Site C operations. Finally K14 (1984 11/bf) and K15 (1984 12/bf) and a 'loess-doll' K16 are from another part of layer K. We do not have gamma spectrometer or capsule measurements for these latter samples and we have assumed the Site C values apply. The TL method used for burned flint has been described by Huxtable and Jacobi (1982). Table 1 gives the measurement data and the ages evaluated for the flints. One flint (K15) had not been drained sufficiently by its first heating to be dated. The 'loess-doll' (K16) from layer K yielded a palaeodose of 45.5 ± 4.5 krad evaluated in the plateau region of the glow curve from 325° to 400°C. This is unlike the behaviour of calcite where growth in this region of the glow curve is non linear. The a value was 0.17 and the calculated age was 175 ± 35 ka. It would be unwise to infer anything from the discrepancy between this TL age and the flint dates as the 'loess-doll' might have been formed during a later pedogenesis.

GAMMA DOSE-RATE FROM THE SOIL

As will be seen from table 1 this is a dominant component of the annual dose. The value used for all flints is that measured with the gamma spectrometer in Unit 4 at the Site C area. The flints were found about 20 cm below the top of this layer and a greater distance above its base. The gamma spectrometer measurement was made 20 cm below the top and at this depth it is estimated that 95% of the dose came from layer K. The dose-rate evaluated for the Unit 5.1 layer above K was higher by 10%.

Table 2 gives the potassium, thorium and uranium concentrations evaluated from gamma spectrometer measurements in various levels of the Belvédère pit.

Dose-rates evaluated from buried capsules were 74 mrad/a for occupation layer (K) of Site C and 84 and 80 for the occupation layer in which K11 was found at Site F. It should be noted that these values include a cosmic ray contribution and that the overburden is not now the same as during antiquity. In calculating the age it is assumed that the average overburden was 2 metres; there is no significant effect on the calculated age for quite large variations in overburden thickness. A more important consideration is that since the flints were at a depth of 20 cm below the top of the layer, and further since the layer above was deposited fairly rapidly, there is a good assurance that flints were receiving the full gamma dose effectively for the whole burial period. If the overburden had been insufficient the calculated age would be less than the true age.

Laboratory measurements of soil alpha radioactivity gave a dose-rate that was 10% lower than the gamma spectrometer evaluation; this was based on thick source alpha counting and alpha spectrometric measurement of polonium-210. The agreement is considered satisfactory, the gamma spectrometer evaluation being preferred as more direct. Comparison of polonium-210 evaluation with thick source alpha counting indicated (45 ± 5%) radon escape, and that the degree of escape before excavation was not significantly different from that obtaining at the time of the gamma spectrometer measurement. Although the radon escape is strong, because there is no evidence for downward diffusion of uranium in table 2 it is considered justifiable to assume that there was no important interference from geochemical leaching.

SEDIMENT DATING

The results for sediment have been obtained by Debenham (see Aitken, Huxtable and Debenham, 1985), where the difficulty in respect of sediments in excess of 100 ka, and to some extent 50 ka is mentioned. For the younger sediments, the upper part of decalcified loess (our ref. *a*) gave an age of 17.2 ± 3.5 ka and the upper part of the calcareous loess (our ref. *d*) an age of 17.5 ± 3.4 ka; for the layer (our ref. *g*) presumed to be the Nagelbeek horizon the age obtained was 13.3 ± 3.0 ka.

CONCLUSION

Based on the 5 flints closest to Site C and from it i.e. K4, 5, 6, 11 and 13 the average age obtained is 270 ka (±11, ±22, OxTL 712 k). Inclusion of K 12 and 14 also would reduce this age by only 3%. The first error limit quoted (see Aitken and Alldred, 1972; Aitken, 1976) gives the standard error derived from the scatter of the individual ages about the mean value. The second one is the predicted error limit taking into account all quantifiable sources of uncertainty. It is the latter limit that should be used in making comparison with dates based on other techniques. Thus at the 68% level of confidence the age can be said to lie within the range 250-290 ka, and at the 95% level within the range 225-315 ka.

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TABLE 1: FLINT TL MEASUREMENTS AND RESULTANT AGES

Sample	*K4*	*K5*	*K6*	*K11*	*K12*	*K13*	*K14*
Palaeodose (krad)							
fine grain	33 ± 3	24.7 ± 1.5	28 ± 1.5	31.3 ± 1.5	29.4 ± 1.4	28 ± 1.8	23.5 ± 1.5
90-125 micron grains	32.2 ± 1.3	27.6 ± 1.3	27 ± 1.3	31.5 ± 2.3	31.9 ± 2.3	27.5 ± 1.8	25.2 ± 1.5
α_0(Ks^{-1})	1.26	0.35	1.60	0.93	1.59	0.94	0.43
$K_2$0 (%)	0.115	0.059	0.076	0.178	0.076	0.062	0.197
a value	0.072	0.098	0.11	0.112	0.115	0.100	0.161
Dose-rates (mrad/a)							
D'_α	8.2	2.8	16.2	9.4	16.8	8.5	6.2
D_β	16.5	6.1	16.4	7.6	16.3	10.6	16.4
$D_{\gamma+c}$	85	85	85	85	85	85	85
Total	110	94	118	102	118	104	107
Age (ka)	300 ± 32	263 ± 27	238 ± 20	307 ± 28	250 ± 21.5	269 ± 26	219 ± 20

1. TL ages have been calculated using the palaeodose for fine grains. Error limits on the ages are at the 68% level of confidence, calculated on the Aitken and Alldred (1972) system.
2. α_0 is the unsealed thick-source count-rate (per ks) for a 42 mm diameter zinc sulphide screen with the electronic threshold setting such that for a thorium only sample the fraction of pulses above the threshold would be 0.85.
3. The gamma dose-rate is derived from the gamma spectrometer measurements made near the find spot of K 4, 5 and 6, i.e. in layer K of Site C. The measured moisture content in the soil at that time was 0.16 of the dry weight. It is assumed that during antiquity the moisture content was 0.16 ± 0.05. The saturation water content was 0.21.
4. The value for the cosmic-ray dose rate has been taken as 13 ± 3 mrad/a, corresponding to an average overburden during burial of 2 metres.
5. D'_α has been taken as (0.75 ± 0.25) of the effective alpha dose-rate assuming homogeneity. The reduction is to allow for the possibility of some anti-correlation between alpha activity and TL sensitivity.

TABLE 2. IN-SITU GAMMA SPECTROMETER EVALUATIONS AT BELVÉDÈRE

	U	*Th*	*K_2O*	*Water content as % of dry weight WC*
	ppm	*ppm*	*%*	*%*
712a	2.3 ± 0.3 (2.7 ± 0.4)	8.2 ± 0.4 (9.6 ± 0.5)	1.73 ± 0.09 (2.03 ± 0.11)	15
c	2.6 ± 0.3	8.2 ± 0.4	1.92 ± 0.09	
d	2.4 ± 0.2 (2.7 ± 0.2)	7.7 ± 0.4 (8.8 ± 0.5)	1.55 ± 0.07 (1.76 ± 0.08)	12
e	2.4 ± 0.2	8.2 ± 0.4	1.56 ± 0.07	
f	3.1 ± 0.2	6.3 ± 0.3	1.45 ± 0.07	
g	2.02 ± 0.14 (2.34 ± 0.16)	8.4 ± 0.2 (9.7 ± 0.2)	1.62 ± 0.06 (1.88 ± 0.07)	14
h	1.83 ± 0.18	9.7 ± 0.3	1.65 ± 0.08	
i	2.14 ± 0.26	8.6 ± 0.4	1.49 ± 0.08	
j	1.59 ± 0.26	7.2 ± 0.4	1.19 ± 0.07	16
k	1.62 ± 0.16	5.8 ± 0.2	1.06 ± 0.05	13

The values quoted are the result of in situ measurement with a gamma spectrometer (sodium iodide). They have not been corrected for water content and hence the values appropriate to dried sediment will be higher by about 15% (on the basis of the water content that has been measured for 5 of the layers, as indicated).

THE MIDDLE PLEISTOCENE (SAALIAN) AND LATE PLEISTOCENE (WEICHSELIAN) MAMMAL FAUNAS FROM MAASTRICHT-BELVÉDÈRE, (SOUTHERN LIMBURG, THE NETHERLANDS)

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CONTENTS

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SUMMARY

The geological sequence exposed in the Belvédère pit consists of Cretaceous-Palaeocene limestone, Tertiary sediments, 5 to 8 metres Middle Pleistocene fluviatile deposits and 6 to 8 metres pre-Weichselian 'loess-like' and Weichselian loess deposits. The lower part of the fluviatile sediments, the coarse gravel, is covered with sandy deposits. The top of the fluviatile sequence consists of loamy sediments.

A sequence of five superposed different mammal fauna-associations from the Maastricht-Belvédère pit has been studied. The oldest association, Belvédère 1, (late Early Pleistocene-early Middle Pleistocene) from the base of the gravel is poorly known. The gravel itself contains a younger fauna-association (Belvédère 2) with tundra elements, for example *Coelodonta antiquitatis,* and is dated as Early Saalian. The base of the overlying sands has yielded a fauna (Belvédère 3) with a number of steppe-elements, such as *Ochotona pusilla* and *Cricetus cricetus praeglacialis.* The next fauna (Belvédère 4) collected from the loamy sediments indicates a more humid and wooded environment. The presence of *Emys orbicularis* in the loamy sediments shows that these sediments have been deposited in a rather warm interval of the Saalian period.

The succession of these Saalian Belvédère 2-4 faunas documents the palaeoecological change during the transition from a cold stadial period to a warm-temperate stage. The presence of a new *Apodemus* species *A. maastrichtiensis* in the faunas Belvédère 3 and 4 (Saalian) is noted.

The high frequency of young individuals amongst the larger mammals of the fauna Belvédère 4, which are found in association with archeological finds, is interpreted to be due to human hunting activity.

The same applies to the presence of the larger mammal remains of the youngest fauna (Belvédère 5) found at the base of the Weichselian loessic deposits. The arctic lemming *Dicrostonyx torquatus* which is abundantly present, indicates that this fauna must be dated as Early Weichselian.

1. INTRODUCTION

Since the archaeological investigations started in 1980, a large number of mammal fossils have been found in the Maastricht-Belvédère pit. Most of them have been collected at the Sites B, C and E (see Roebroeks, 1985) during the excavations and during a special campaign organized to search for fossils of micromammals in the deposits exposed in the Maastricht-Belvédère pit.

A large number of fossils of for example mammoth, woolly rhino and horse were collected from the sediments of the Caberg terrace many years ago. Some of them have been studied and described by Rutten (1909) and Cremers (1925, 1926). These fossils are stored in the Museum of Natural History Maastricht (NHMM) and the Netherlands National Museum of Geology and Mineralogy (R.G.M.) at Leiden. These fossils have been restudied, but are mentioned in this article only when the stratigraphical position of the specimen is known.

Five superposed different mammal fauna-associations from the Maastricht-Belvédère pit are described in this paper. Four of them have been found in the fluviatile deposits which overlie the Cretaceous-Palaeocene limestone and Tertiary sediments and which are covered with 'loess-like' and loess deposits. A detailed description of the lithostratigraphy is presented by Vandenberghe et al. (1985).

The base of the gravels (Unit 3), the lowermost part of the fluviatile deposits, has yielded the oldest fauna-association (Belvédère 1). Mammal fossils of a younger fauna-association (Belvédère 2) are found in the upper part of the gravels. The base of the overlying fine-grained Maas deposits (Unit 4) contains a fauna-association (Belvédère 3) which differs from the Belvédère 4 fauna-association from higher up in Unit 4. Unit 5.2, on top of the fluviatile sediments, partly consists of reworked material from the underlying sediments. The faunal remains from this Unit (site B, see Roebroeks, 1985) are regarded as being part of the fauna-association Belvédère 4.

The youngest fauna-association (Belvédère 5) collected at site E derives from Unit 6.2, the base of the Weichselian loessic deposits.

2. TERMINOLOGY AND MEASUREMENTS

All the elements of the upper jaw are indicated with a capital character, the elements of the lower jaw by a small character.

The terminology used with the description of the fossils and the way of measuring them are specific in some cases. The authors who describe and figure the nomenclature and the measuring methods are mentioned in the section dealing with the species concerned.

3. ACKNOWLEDGEMENTS

I am greatly indebted to A. J. van der Meulen and P. Y. Sondaar for their support and to A. J. van der Meulen, P. Y. Sondaar, P. Marks, W. H. Zagwijn, W. Roebroeks and D. F. Mayhew for critical reading of the manuscript and constructive comments.

The author is grateful to A. W. F. Meijer (Maastricht), M. Freudenthal (Leiden), P. H. J. van Bree (Amsterdam) and C. Smeenk (Leiden) for permission to study the collections.

I should like to thank H. P. Brinkerink for his assistance in the field and the preparation of part of the fossils. J. Luteijn made the drawings and W. A. den Hartog made the pictures, for which I am grateful. I should like to thank D. F. Mayhew for improving the English text.

I grateful acknowledge the Netherlands Organization for the Advancement of Pure Research (Z.W.O.) for their financial support for my research on the biostratigraphy of Middle Pleistocene mammals from The Netherlands of which this project is part.

4. SYSTEMATIC DESCRIPTIONS

4.1. PISCES

Drs. D. C. Brinkhuizen (B.A.I., Groningen) determined some fish remains. Amongst the fossils of the faunas Belvédère 3 and 4 there are pharyngeal teeth of carp-like fish (Cyprinidae) such as *Leuciscus cephalus* (Linnaeus, 1758), the chub, and *Chondrostoma nasus* (Linnaeus, 1758), the nase. Dental teeth of the pike, *Esox lucius* Linnaeus, 1758 indicate the presence of this species in the fauna Belvédère 4.

4.2. AVES

The bird remains have been determined by Drs. P. Weesie, Institute for Earth Sciences, Utrecht.

Aves indet.

Fauna; Belvédère 4
Material: first phalange Dig. III, bone fragments

Remarks
The first phalange has no special morphological characters. It has the size of the heron (*Ardea cinerea*). The bone fragments are indeterminable and probably belong to small perching birds (Passeriformes).

Anatidae indet.

Fauna; Belvédère 4
Material: coracoid sin.

Fig. 1. *Nyctea scandiaca:* tarsometatarsale dext. (BWG 1), posterior view.

Remarks
The coracoid is incomplete. Proximally a small fragment is missing and the distal articulation surface is entirely broken off. Morphologically it looks like a coracoid of the Anseriformes. The size of the specimen from the Belvédère is intermediate between a mallard (*Anas platyrhynchos*) and a graylag goose (*Anser anser*).

Nyctea scandiaca (Linnaeus, 1758)
(Snowy owl)
(Fig. 1)

Fauna; Belvédère 5
Material: tarsometatarsale dext.

Remarks
The tarsometatarsale has been referred to this species on the basis of the identity in size and morphology with comparative material of the recent snowy owl.

4.3. REPTILIA

Emys orbicularis (Linnaeus, 1758)
(European pond tortoise)
(Fig. 2)

Fauna; Belvédère 4
Unit: 4b
Material: epiplastron dext., hypoplastron sin. (posterior part), xiphiplastron (anterior part).

Unit: 5.2.
Material: supra-pygale 2, fragm. costale, marginale 7 sin., marginale 9 dext., marginale 10 dext., fragm. hyoplastron, fragm. xiphiplastron.

Description and remarks (the nomenclature of the bones is figured in Fig. 2a and b)

The remains of the hypoplastron and the xiphiplastron from unit 4b are found together, close to the epiplastron. In view of their position in the layer and of their comparable size these remains probably belonged to one individual (see Fig. 2c). The length of the plastron has been estimated to be about 14 cm.

The difference in size of the remains from unit 5.2 indicate that they derived from at least two specimens. The imprint of the suture of the horny plates on the marginal bones shows that the costal horny plates partly overlie the marginal bones. This character is typical for *E. orbicularis* (Brinkerink, pers. comm., 1985), the only tortoise species known from Pleistocene deposits of North Western Europe (Stuart, 1979).

4.4. MAMMALIA

4.4.1. Insectivora

4.4.1.1. Erinaceidae

Erinaceus cf. *davidi* Jammot, 1973
(Hedgehog)
(Fig. 3a)

Fauna; Belvédère 4
Material: M2 dext.
Measurements: length –, width 5.05 mm.

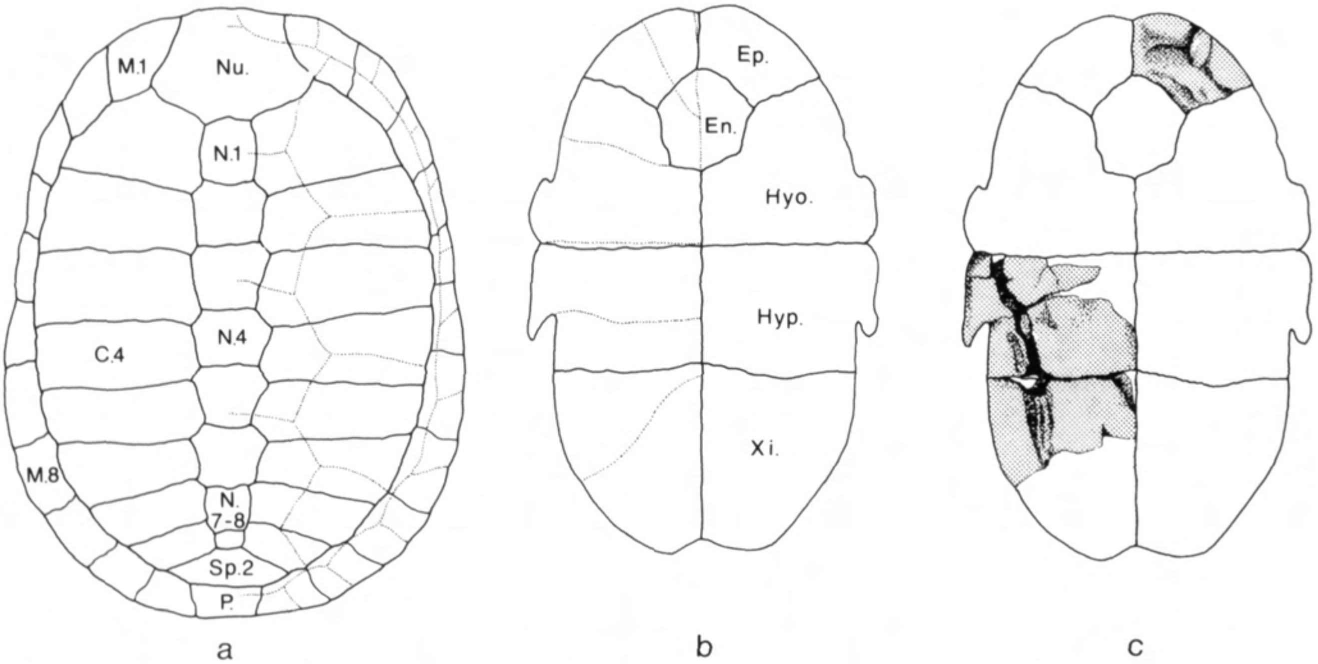

Fig. 2. Shell of *Emys orbicularis* L. (a and b modified from Stuart, 1979). Dotted lines on the right hand side of the shell indicate margins of the overlying horny plates. a: carapace; dorsal view. Nu = nuchal, N1-8 = neurals, C1-8 = costals, M1-11 = marginals, P = pygals, Sp 1-2 – supra-pygals b: plastron, ventral view. Ep = epiplastron, En = entoplastron, Hyo = hyoplastron, Hyp = hypoplastron, Xi = xiphiplastron. c: parts of plastron (dorsal view). Belvédère 4.

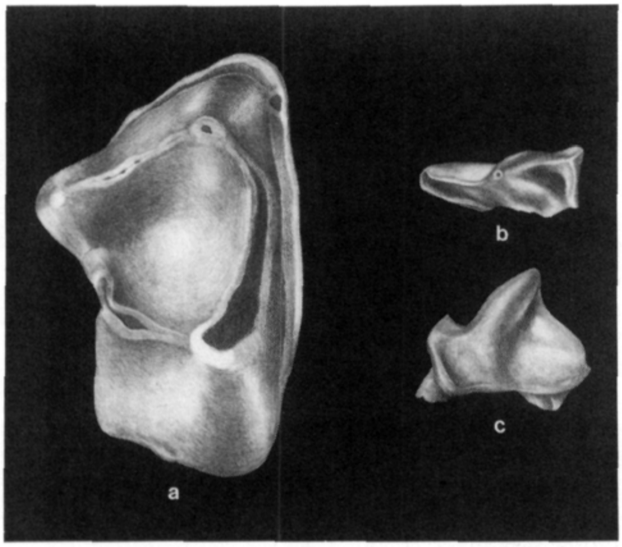

Fig. 3. a: *Erinaceus* cf. *davidi:* occlusal view of M2 dext. (BL 9-1); b-c: *Crocidura* cf. *leucodon:* P4 dext. (BL 4-16) a: occlusal view; b: buccal view. Enlargement 10 x.

Description

The element is incomplete. Hypocone and metacone are missing. The molar has a large protocone and a high and sharply pointed paracone. Protocone and paracone are connected by a high crest. A lower crest is present between paracone and metacone and a very low and short one between protocone and metaconule. The molar has a wide anterior cingulum and a narrow buccal one.

Remarks

There are a number of differences between the M2 of the living *Erinaceus europaeus* and the specimen from the Belvédère. The molar from the Belvédère has

- more pointed tubercles
- a crest between paracone and metacone (absent at the M2 of *E. europaeus*)
- a narrow buccal cingulum
- a more anteriorly situated metaconule

Because of these differences it is doubtful that the molar belongs to *Erinaceus europaeus. Aethechinus algirus,* the Vagrant Hedgehog, which lives in Africa and certain areas of Southern Europe can be distinguished from *E. europaeus* on the basis of differences of the anterior dental elements. The upper molars of these two species are more or less identical. Assignment to *Aethechinus algirus* is unlikely.

Jammot (1973) describes a new species *Erinaceus davidi* from the Middle Pleistocene site La Fage. It is the largest European hedgehog known so far (Jammot, 1973). The width of the M2 from the Belvédère fits within the range of the M2 of *E. davidi* from La Fage (M2 width; 4.6-6.1 mm, mean 5.2 mm (N=5)). Additionally the morphology of our specimen seems to correspond rather well to that of the M2 of *E. davidi* figured by Jammot, 1973 (Plate 2, Fig. 9).

4.4.1.2. Talpidae

Talpa europaea Linnaeus, 1758
(Mole)

Fauna; Belvédère 3
Material: M3 sin., m2 sin., m3 dext., humerus sin., ulna sin.

Measurements: (the humeri are measured according to the method figured by Jammot, 1973.)

humerus; width of the diaphysis 4.3 mm

Fauna; Belvédère 4
Material: I 1 dext., I 2 dext., I 2 sin., C dext., C sin., 3 P4 dext., 2 P4 sin., 2 M1 dext., M1 sin., 4 M2 dext., 3 M2 sin., 3 M3 dext., M3 sin, 2 mandibula dext., 2 mandibula sin., 3 c dext., 2 p2 dext., p2 sin., p3 dext., 5 m1 dext., 4 m2 dext., 4 m2 sin., 3 m3 dext., humerus dext., 4 humerus sin.

Measurements: (the molars are measured according to the method described and figured by Reumer, 1984)

m1	N	Min.	Max.	x̄
TRW	5	0.96	1.12	1.04
TAW	4	1.17	1.35	1.24
L	3	2.18	2.22	2.19
m2				
width	8	2.15	2.61	2.41
length	8	1.08	1.39	1.29
humerus;				
length	2	15.8	16.5	16.2
width of the diaphysis	5	4.1	4.7	4.3
distal width	5	8.4	9.1	8.8

Fauna; Belvédère 5
Material: humerus sin.

Measurements:
humerus; width of the diaphysis 4.0
distal width 8.6

Description and remarks

The fossils from Belvédère show much resemblance to material of the living *Talpa europaea.* There are a few differences. All M1 from Belvédère, except for one specimen, have a relatively small lingual part, the posterior crest on the protocone is poorly developed and the protocone itself is also smaller. These features are variable in the M1 of the living *Talpa europaea,* but their lingual part is usually larger and better developed.

The dental material from Belvédère is smaller than that of the living *T. europaea.* The means of length and width of the m2 from a single recent population (N = 30) from The Netherlands are 2.60 mm and 1.48 mm respectively. The humeri from the same population (N = 30) have about the same size (mean distal width 8.94) as those from the different units of the Belvédère.

Comparison with the measurements of humeri from the Middle Pleistocene site Petersbuch (Von Koenigswald, 1970) indicates that the humeri from Belvédère are much larger than those of *T. minor* and also larger than most of the humeri of *T. europaea* from Petersbuch. The dimensions agree better with the humeri from La Fage (Jammot, 1973). Dental material of *T. europaea* is poorly represented at the site Petersbuch and La Fage which makes comparison difficult.

4.4.1.3. Soricidae

The presence or absence of the pigmentation of the teeth is an important diagnostic character for the genera of this family. Unfortunately the material from Belvédère does not show any trace of pigmentation. Therefore, the determination is based on other morphological characters and on size.

The measurements and terminology are according to Reumer, 1984.

Sorex araneus Linnaeus, 1758
(Common shrew)

Fauna; Belvédère 3
Material: M1 dext., M2 dext., i dext. i sin.

Fauna; Belvédère 4
Material: 4 I dext., 9 I sin., 2 P4 dext., 6 P4 sin., 4 M1 dext., 5 M1 sin., 3 M2 dext., 4 M2 sin., mandibula with p4 dext., mandibula with m1 dext., mandibula with m2 and m3 dext., mandibula with m1 and m2 sin., 1 ramus dext., 2 rami sin., 5 i dext., 3 i sin., 4 p4 sin., 5 m1 dext., 6 m1 sin., 3 m2 dext., 1 m2 sin., 1 m3 sin.

Remarks

The Belvédère material is so similar to recent material of *S. araneus,* with which it has been compared, that we refrain from further description.

Sorex minutus Linnaeus, 1758
(Pygmy shrew)

Fauna; Belvédère 4
Material: 2 I sin., P4 dext., 2 P4 sin., 2 M1 sin., 4 M2 sin., mandibula with m1 and m2 dext., mandibula with m2 sin., 4 i dext., 2 sin., 2 m1 sin., 2 m2 dext.

Measurements:

		N	Min	Max.	x̄
i inf.	length	4	2.51	3.00	2.73
m1	TRW	3	0.58	0.67	0.61
	TAW	3	0.63	0.67	0.65
	L	3	1.03	1.10	1.06
m2	TRW	3	0.58	0.73	0.63
	TAW	3	0.58	0.71	0.63
	L	4	1.04	1.09	1.05
ramus	length –				
	height 3.02				
	LUF 0.54				
	LLF 0.80				
	HC 1.04				

Description and remarks

Characteristic for *Sorex minutus* is the small size and the great morphological resemblance with *Sorex araneus* except for the upper incisors, which are fissident in *S. minutus.* Additionally one specimen, which is little worn, possesses an isolated accessory cusp at the internal side of the talon, another feature not known in *S. araneus.*

The mental foramen of the mandibula is situated below the paraconid of the m1. This excludes determination as *S. minutissimus,* in which the mental foramen is situated below the middle of the m1 (Heim de Balsac, 1940).

The fossils of *S. minutus* from Belvédère are smaller than those from the Early Pleistocene site Tegelen (Reumer, 1984). Most of the mean values of the Belvédère fossils are also lower than those of the Ruscinian material studied by Reumer (1984). Apparantly the slight increase in size of *S. minutus* during the Late Pliocene and the Early Pleistocene according to Reumer (1984) did not continue during the Middle Pleistocene. Material of *S. minutus* from Middle Pleistocene sites like Sudmer-Berg-2 (Von Koenigswald, 1972), Miesenheim (own observations), Tornewton Cave (Rzebik, 1968) and Ehringsdorf (Heinrich, 1981c) is of similar size to that from the Belvédère-pit.

Neomys fodiens Pennant, 1771
(Water shrew)

Fauna; Belvédère 3
Material: I sin., mandibula with i and p4 - m3 sin., m2 sin.

Fauna; Belvédère 4
Material: I dext., P4 dext., P4 sin., M2 dext., mandibula dext., mandibula with p4 and m1 sin., mandibula sin., p4 dext., p4 sin., 3 m1 dext., 3 m1 sin., 2 m2 dext., m2 sin.

Measurements: see description and remarks

Description and remarks
The presence of *Neomys* fossils is clearly indicated by a number of mandibulae with condyles in which the articular facets are separated, and with unicuspulate lower incisors (see Chaline et. al., 1974). The upper incisors are fissident and have a large apex.

The molars of *Neomys* and *Sorex* resemble each other in morphology. The upper molars of *Neomys* have somewhat higher cusps and a better developed hypocone. The talonid of m1 and m2 of *Neomys* is better developed than the trigonid (Chaline et al., 1974). The isolated teeth have been determined as *Neomys* on these characters.
One of the three mandibles has a coronoid process with a height of 4.80 mm which is too high for *Neomys anomalus milleri* (Chaline et al., 1974). The value is within the range of *Neomys fodiens fodiens* (Chaline et al., 1974). The other mandibulae have a lower coronoid process with a height of 4.37 and 4.48 mm. These measurements fall in the ranges of both species.

Crocidura cf. *leucodon* (Hermann, 1780)
(Bicoloured shrew)
(Fig. 3b and c)

Fauna; Belvédère 4
Material: P4 dext.
Measurements: lenght 2.05 mm, height 1.66 mm.

Description and remarks
The lingual part of this P4 is broken off. The premolar has a well developed paracone slightly separated from the high metacone. In these characters it resembles a P4 of the biocoloured shrew *C. leucodon* and differs from the white-toothed shrew *C. russula* which has a more isolated and smaller paracone. Paracone and metacone of the P4 of *C. suaveolens* are also slightly separated but the anterior arm of the paracone is bent towards the lingual side (Chaline et al., 1974). The P4 of *C. leucodon* and the specimen from the Belvédère have a straight paracone.

Soricidae indet.

Fauna; Belvédère 3
Material: mandibula fragment

Fauna; Belvédère 4
Material: I dext., 2 P4 dext./sin., 2 M1 dext., 2 M1 sin., 3 M2 dext., M2 sin., 3 M1/M2 sin., 2 mandibula fragm., i sin., m1 dext., m2 dext., m2 sin.,

Remarks
Most of this material is incomplete and does not show any diagnostic characters. Therefore, it is impossible to give a specific determination.

4.4.2. Lagomorpha

4.4.2.1. Ochotonidae
Ochotona pusilla Pallas, (1769)
(Steppe pika)
(Fig. 4)

Fig. 4. *Ochotona pusilla:* occlusal view of P4 dext. (BZ 4-151). Enlargement 25 x.

Fauna; Belvédère 3
Material: P4 dext.
Measurements: length 0.88 mm., width 1.79 mm.

Description and remarks
The morphology of this specimen is characteristic of the P4 of *Ochotona*. The measurements of fossil and living species of *Ochotona*, given by Tobien (1972) indicate that the size of this specimen fits in the range of *O. pusilla*.

4.4.3. Rodentia

4.4.3.1. Sciuridae
Spermophilus (Urocitellus) cf. *undulatus* Pallas, 1779
(Longtailed souslik)
(Fig. 5)

Fauna; Belvédère 3
Material: M1/2 dext., M3 dext.

Measurements:	M1/2	length 2.94 mm	width 3.58 mm
	M3	length 3.24 mm	width 3.19 mm

Fauna; Belvédère 5
Material: P3 dext., M1/2 dext., dp4 dext., p4 dext., m1/2 dext., 2 m1/2 sin., m3 sin.

Measurements:	P3	length 1.78 mm	width 1.99 mm
	M1/2	length 2.65 mm	width 3.31 mm
	dp4	length 1.97 mm	width 1.81 mm
	p4	length 2.19 mm	width 2.27 mm
	m1/2	length 2.41 mm	width 2.99 mm
		length 2.47 mm	width 3.02 mm
		length 2.56 mm	width –
	m3	length –	width –

Description
The upper molars are characterized by a relatively small protocone, fairly weak developed lophs and a

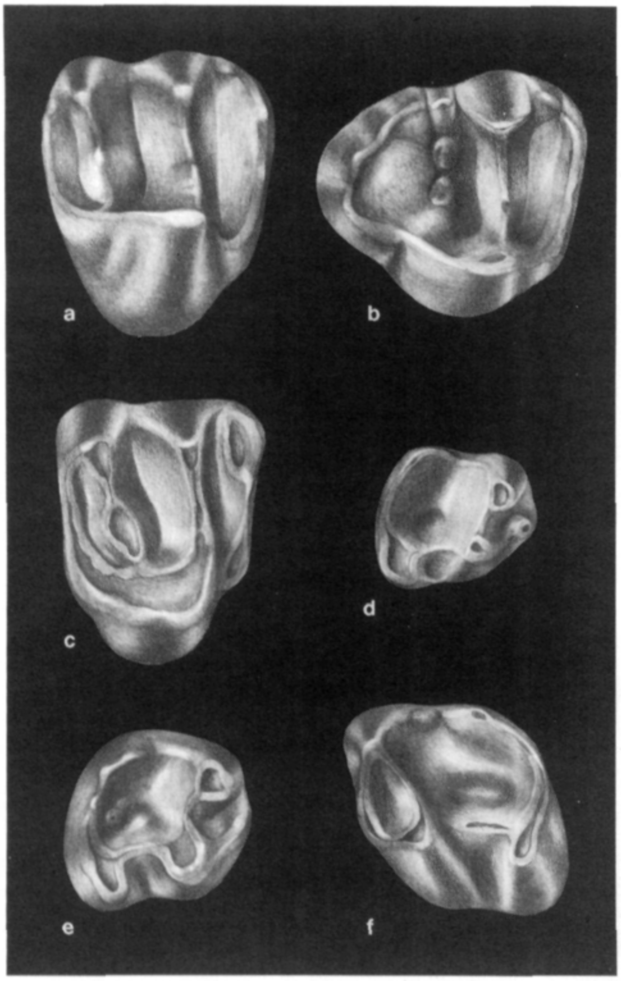

Fig. 5. *Spermophilus (U.)* cf. *undalatus:* a and b: Belvédère 3; c-f: Belvédère 5. a: M1/2 dext. (BZ 1-162); b: M3 dext. (BZ 1-161); c: M1/2 dext. (BWG 104); d: dp4 dext. (BWG 101); e: p4 dext. (BWG-103); f: m1/2 sin. (BWG-107). Enlargement 10 x.

more or less distinct metaconule. The posteroloph is well developed and connected with the posterior arm of the protocone. There is no posterior cingulum. The upper molars M1/2 show some variation in the development of the anterior cingulum. The specimen from fauna Belvédère 3 has a larger cingulum than the one from fauna Belvédère 5.

The little worn crown of the milk-molar has thin enamel, well developed lophs and a distinct anteroconid. The lower (pre)molars have a large protoconid, a distinct posterior margin of the trigonid basin and a rounded outline. The floor of the talonid basin of the p4 is crenulated. That of the molars is rather smooth. The P3 has one root, the M1/2 and M3 three and the p4 two roots.

Remarks

The Sciurid teeth from the Belvédère faunas 3 and 5 belong to a medium-sized groundsquirrel. The material show characters of *S. (U.) undulatus* from the Late Pleistocene site Crayford (Mayhew, 1975). In spite of the small variation in the development of the anterior cingulum, it is thought that all the material belongs to one single species.

4.4.3.2. Gliridae Thomas, 1987

Terminology and measurements are according to Daams (1981)

Eliomys quercinus Linnaeus, 1766
(Garden dormouse)

Fauna; Belvédère 4
Material: m2 dext.
Measurements; length 1.36 mm., width 1.61 mm.

Description

The molar is low-crowned, nearly unworn and has three roots. There are 4 ridges on the occlusal surface without any extra ridges. Its size and morphology corresponds with the living *E. quercinus.*

4.4.3.3. Cricetidae

Cricetus cricetus praeglacialis Schaub, 1930
(Hamster)
(Fig. 6a)

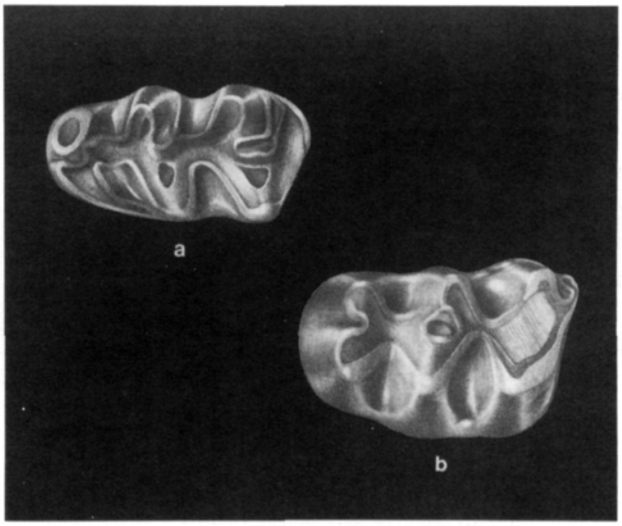

Fig. 6. a: *Cricetus cricetus praeglacialis:* m1 sin. (BZ 1-171), Enlargement 10 x; b: *Cricetulus migratorius:* M1 dext. (BWG 115). Enlargement 20 x.

Fauna; Belvédère 3 ,
Material: m1 sin.
Measurements: length 3.28 mm., width 1.80 mm.

Description and remarks

The specimen is a worn m1 with a morphology which is characteristic for *Cricetus.* The two tubercles of the anteroconid have about the same size. The two anteroconid-tubercles of the m1 of the living *Cricetus cricetus* differ in size, are more isolated from each other and situated more labially than those of the specimen from the Belvédère.

The symmetrical anterior part of the m1 and the size correspond very well with *Cricetus cricetus praeglacialis* known for instance from the Early Pleistocene sites Nagyharsányberg, Beremend (Schaub, 1930) and Les Valerots (Chaline, 1972). The molar from the Belvédère is larger than the m1 of *Cricetus cricetus* from Ehringsdorf (length 2.90 mm.) (Heinrich, 1981c) but too small to be assigned to *Cricetus major* (see Fahlbusch, 1976).

Cricetulus migratorius (Pallas, 1773)
(Grey hamster)
(Fig. 6b)

Fauna; Belvédère 5
Material: M1 dext.
Measurements: M1 length 1.65 mm, width 1.23 mm

Description and remarks

The small hamster is represented by only one, worn first upper molar. The morphology of the specimen resembles that of the M1 molars of *Cricetulus migratorius* from Arnissa (Mayhew, 1978). Mayhew preferred to use the name *Cr. migratorius* rather than the name *Allocricetus bursae* for Late Pleistocene small hamsters because in his opinion dental material of *Allocricetus bursae* is indistinguishable from the living *Cr. migratorius*.

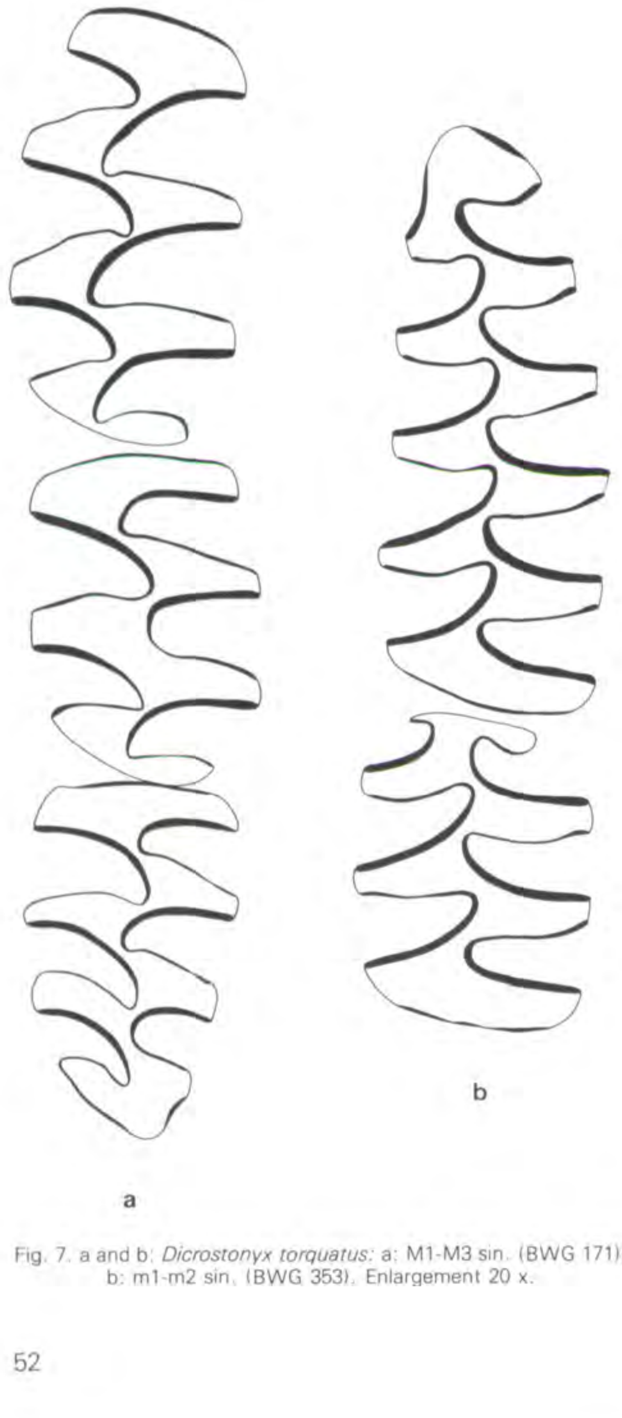

Fig. 7. a and b: *Dicrostonyx torquatus*: a: M1-M3 sin. (BWG 171); b: m1-m2 sin. (BWG 353). Enlargement 20 x.

4.4.3.4. Arvicolidae

The terminology is according to Van der Meulen, 1973.

Dicrostonyx torquatus (Pallas, 1779)
(Arctic lemming)
(Fig. 7)

Fauna; Belvédère 5
Material: maxilla with M1 and M2 dext., maxilla with M1 - M3 sin., Maxilla with M2 and M3 dext., maxilla with M2 and M3 sin., 8 M1 dext., 9 M1 sin., 7 M2 dext., 7 M2 sin., 11 M3 dext., 10 M3 sin. 2 mandibulae with m1 and m2 dext., mandibula with m1-m3 sin., 3 mandibula with m1 and m2 sin., 37 m1 dext., 32 m1 sin., 34 m2 dext., 31 m2 sin., 8 m3 dext., 16 m3 sin.

Measurements:

		N	Min.	Max.	$\bar{x}$
M1;	length	11	2.45	2.95	2.69
	width	18	1.36	1.57	1.46
M2;	length	16	1.90	2.28	2.09
	width	18	1.37	1.62	1.48
M3;	length	18	2.19	2.70	2.36
	width	21	1.23	1.50	1.36
m1;	length	45	3.20	4.15	3.70
	width	56	1.23	1.51	1.39
m2;	length	50	1.52	2.36	1.90
	width	63	1.20	1.65	1.38
m3;	length	17	1.37	2.00	1.78
	width	21	1.07	1.42	1.28

Description

The molars are rootless and lack crown-cementum. The enamel thickness is conspicuously differentiated. The enamel of the posterior sides of the triangles is thicker than at the anterior side in the upper molars. In the lower molars the situation is reversed. The enamel is absent at the tips of the salient angles.

The M1 comprises an anterior lobe, five alternating, closed triangles and postero-buccally a narrow elongated field. The entire posterior side of the M1 lacks enamel (morphotype 1 of Agadjanian & Von Koenigswald, 1977). The morphology of the posterior part of most of the M2 molars is the same as that of the M1 (morphotype 1 of Agadjanian & Von Koenigswald, 1977). Only two specimens out of nineteen have a different morphology. They have enamel at the posterior side of TC4 and a small third lingual re-entrant angle (morphotype 2 of Agadjanian & Von Koenigswald, 1977). The M3 has an anterior lobe, four triangles and a posterior cap. Some molars have enamel only at the postero-buccal side of the cap (morphotype 2 of Agadjanian & Von Koenigswald, 1977). Others have enamel at the postero-buccal and the postero-lingual side of the cap (morphotype 3 of Agadjanian & Von Koenigswald, 1977). But there are also specimens in which there is no enamel at the posterior side (morphotype 1 of Agadjanian & Von Koenigswald, 1977).

The m1 has a posterior lobe, 7 triangles and an anterior cap. The morphology of the anterior cap is variable. Twelve specimens (20%) have a simple cap without re-entrant angles (morphotype 1 of Agadjanian, 1976). Six specimens (10%) have a sixth re-entrant angle at the lingual side (LRA 6) (morphotype 2 of Agadjanian, 1976). The other specimens (70%) have a sometimes poorly developed LRA 6 and a shallow fifth buccal re-entrant angle (BRA 5) (morphotype 3 and 4 of Agadjanian, 1976). A sixth buccal salient angle (BSA 6) is present in 4 specimens (6%) with morphotype 4 of Agadjanian, 1976. In 3 specimens the T8 is closed and one of them has also a T9. These molars can also be assigned to morphotype 4 of Agadjanian (1976).

The m2 and the m3 have the normal *Dicrostonyx* pattern.

Remarks

In the recent fauna one can distinguish two species belonging to the genus *Dicrostonyx; D. hudsonius* (Pallas, 1779) which inhabits an isolated territory in Labrador (Canada) and *D. torquatus* (Pallas, 1779) with a holarctic distribution. Four fossil *Dicrostonyx* species have been described from European Pleistocene deposits; *D. gulielmi, D. henseli, D. simplicior* and *D. antiquitatis. D. antiquitatis* is known from the Early Middle Pleistocene site Les Valerots (Chaline, 1972). This species only has 5 closed triangles in the m1. The other species are more advanced in having m1 with at least 7 closed triangles. They differ from each other in the patterns of the occlusal surfaces of the M1, M2, M3 and m1. Agadjanian (1976) distinguishes four different morphotypes for each of the different elements. These morphotypes have been numbered I through IV, the higher the number, the more complicated the occlusal pattern. In the opinion of Agadjanian & Von Koenigswald (1977) there are, apart from *D. antiquitatis,* four living and fossil species all together. *D. simplicior* and *D. hudsonius* characterized by M1 and M2 which belong exclusive to morphotype I, *D. gulielmi* (= *D. henseli* and partly *D. torquatus*) with three subspecies *D. gulielmi rotundus, D. gulielmi henseli* and *D. gulielmi gulielmi* characterized by M1 and M2 showing the preponderance of morphotypes I, II and III respectively. The fourth species, *D. torquatus,* is characterized by the occurrence of morphotypes III and IV of the M1 and M2. The relative frequencies of the different morphotypes change during the Middle and Late Pleistocene (Agadjanian, 1976 and Agadjanian & Von Koenigswald, 1977). The distribution of the different morphotypes of the M1 and the M2, in particular, can be used stratigraphically. The M1 and M2 with a high frequency of morphotype I are restricted to the Middle Pleistocene. The M1 and the M2 with a Middle Weichselian age mostly have morphotype I and sometimes morphotype II. The other morphotypes are more frequent in more recent material.

All M1 and nearly all M2 from Belvédère 5 belong to morphotype I. Only 2 M2 (out of 19) are more complicated (morphotype 2). This suggests that the fauna has a pre-Middle Weichselian age.

According to Jánossy (1954) all these morphotypes are present in the recent *D. torquatus* and he suggest therefore that all the fossil material referred to *D. simplicior, D. gulielmi* and *D. henseli* should be assigned to *D. torquatus.* This opinion has been supported by Chaline (1972), Van der Meulen in Van der Meulen & Zagwijn (1974) and the present author. The distinction of fossil *Dicrostonyx* (sub)species on the base of the relative frequency of morphotypes as purposed by Agadjanian & Von Koenigswald (1977) can only be done if sufficient material is available. So, for practical reasons it is preferable to assign all fossil material which falls within the variation of *D. torquatus,* to that species.

Clethrionomys glareolus (Schreber, 1780)
(Bank vole)

Fauna; Belvédère 3
Material: M1 dext., M1 sin., M2 dext., 2 M2 sin., m1 dext., m1 sin., m3 dext., 3 m3 sin.

Measurements:

		N	Min.	Max.	$\bar{x}$
M1	length	2	1.74	1.90	1.82
	width	2	0.92	0.96	0.94
M2	length	3	1.22	1.44	1.35
	width	3	0.79	0.94	0.87
m1	length	2	2.02	2.17	2.09
	width	2	0.91	0.95	0.93
m3	length	4	1.11	1.32	1.23
	width	4	0.59	0.68	0.63

Fauna; Belvédère 4
Material: 8 M1 dext., 11 M1 sin., 8 M2 dext., 7 M2 sin., 8 M3 dext., 10 M3 sin., 6 m1 dext., 11 m1 sin., 16 m2 dext., 6 m2 sin., 16 m3 dext., 15 m3 sin.

Measurements:

		N	Min.	Max.	$\bar{x}$
M1	length	18	1.67	1.96	1.79
	width	18	0.83	1.09	0.93
M2	length	15	1.24	1.45	1.33
	width	15	0.70	0.93	0.82
M3	length	17	1.41	1.72	1.56
	width	18	0.62	0.79	0.73
m1	length	12	1.97	2.25	2.06
	width	14	0.83	0.94	0.87
m2	length	17	1.20	1.36	1.30
	width	20	0.72	0.87	0.78
m3	length	28	1.11	1.53	1.27
	width	28	0.57	0.85	0.69

Description and remarks

The molars have two roots each and relatively thick enamel. The elements of young specimens are rootless and have thinner enamel. The molars have crown-cement in the re-entrant folds and the salient angles are rounded at their tips. The m1 has four narrowly confluent triangles and a fifth triangle which is broadly confluent with a simple anterior cap. The morphology of the M3 is variable. In some a well developed fourth lingual salient angle is present, in other M3 it is small or absent. A fourth buccal salient angle is incipient or absent. The morphology of these molars is similar to those of the living *Clethrionomys glareolus.*

Arvicola cantiana/terrestris

(Fig. 8a)

Fauna; Belvédère 3
Material: M1 dext., M1 sin., M3 dext., 3 M3 sin., m1 dext. m1 sin., 2 m2 sin., m3 dext., m3 sin.

Measurements:

		N	Min.	Max.	$\bar{x}$
M1	length	1	3.04		
	width	1	1.74		
M3	length	1	2.23		
	width	2	1.06	1.12	1.09
m1	length	–			
	width	2	1.48	1.56	1.52
m2	length	1	2.17		
	width	1	1.32		
m3	length	1	2.12		
	width	2	0.98	1.13	1.06

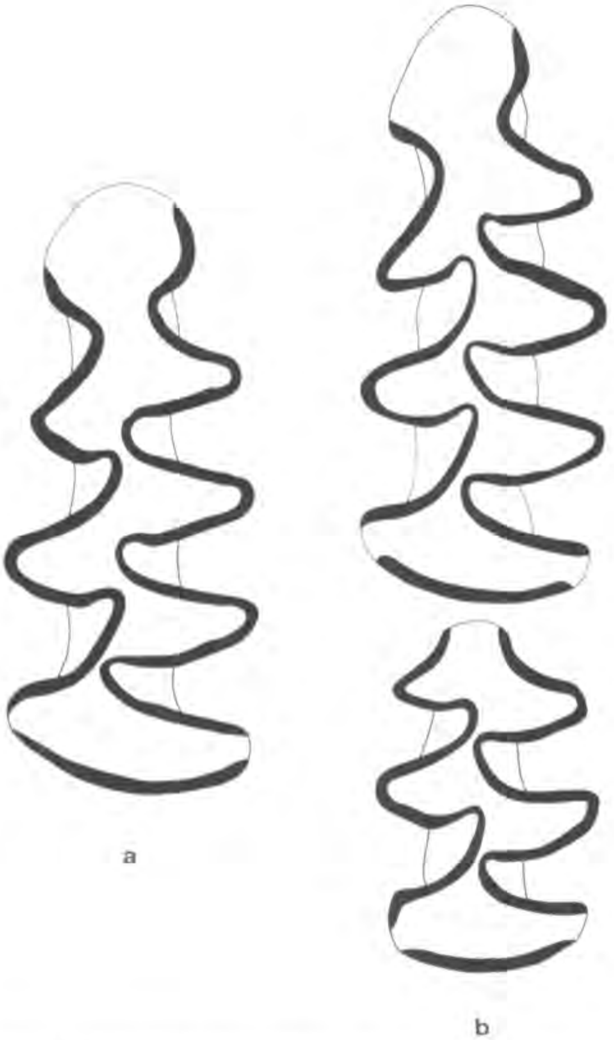

Fig. 8 a: *Arvicola cantiana/terrestris:* m1 sin. (BL 3-306); b: *Arvicola terrestris:* m1 and m2 sin. (BWG 501). Enlargement 20 x.

Fauna; Belvédère 4
Material: 6 M1 dext., M1 sin., 7 M2 dext., 1 M2 sin., 6 M1/M2, 2 M3 dext., 2 M3 sin., 3 m1 dext., 2 m1 sin., 4 m2 dext., 4 m2 sin., 4 m3 dext., 3 m3 sin.

Measurements:

		N	Min.	Max	x̄
M1	length	7	2.92	3.20	3.08
	width	7	1.66	1.80	1.74
M2	length	7	2.12	2.57	2.27
	width	7	1.31	1.62	1.44
M3	length	4	1.86	2.20	2.10
	width	4	1.15	1.24	1.20
m1	length	5	3.21	3.88	3.65
	width	5	1.30	1.60	1.51
m2	length	5	2.13	2.34	2.20
	width	6	1.27	1.48	1.37
m3	length	5	1.94	2.11	1.98
	width	5	0.97	1.18	1.05

Description and remarks

All the molars are rootless, their re-entrant folds are partly filled with crown-cement. The m1 comprises, a posterior loop, three closed triangles and a relatively large anterior loop. The enamel on the convex side of the triangles is as thick as that on the concave side. The mean size of the m1 is somewhat larger than those of *Arvicola cantiana* from Westbury-sub-Mendip (Bishop, 1982). They have about the same size as the molars of *A. terrestris* from Rhenen which have a mean length of 3.53 mm. (N = 2) (Van Kolfschoten, 1981).

Arvicola molars in which the enamel thickness is not differentiated are currently determined as *A. cantiana/terrestris* indicating the transitional stage in the evolution from *A. cantiana* to *A. terrestris*.

Arvicola terrestris (Linneaus, 1758)
(water vole)
(Fig. 8b)

Fauna; Belvédère 5
Material: 2 m1 sin., m2 sin.

Measurements:

		N	Min.	Max.	x̄
m1	length	1	—	—	3.78
	width	2	1.55	1.65	1.60
m2	length	1	—	—	2.18
	width	1	—	—	1.40

Description

The *Arvicola* teeth from Belvédère 5, the m1 in particular, show a differentiation of the enamel thickness. In the lower teeth the enamel on the convex side of the triangles is somewhat thinner than on the concave side (see Fig. 8b). This type of enamel-thickness differentiation and the size of the material allow the determination of this material as *Arvicola terrestris*.

Remarks

The *Arvicola* teeth from Belvédère 5 differ from the *Arvicola* teeth from the faunas 3 and 4 by their enamel differentiation. The mean length of the m1 of recent watervoles from England is about 4.35 mm (Stuart, 1982). The measurements of those of *A. terrestris terrestris* and *A. terrestris exitus* from Poland are respectively 4.18 mm and 3.91 mm (Nadachowski, 1982). This indicates that the modern watervole is a little larger than the one from the fauna Belvédère 5.

Pitymys McMurtrie, 1831 and *Microtus* Schrank, 1798.

A large number of molars represent the genera *Pitymys* or *Microtus* in the faunas Belvédère 3, 4 and 5. The molars agree in the absence of roots, the presence of abundant crown-cement in the synclines and differentiation of the enamel thickness at both sides of the triangles. Only the occlusal patterns of m1 and partly those of M2 and M3 are useful for determination.

The occlusal surface of the m1 displays a posterior lobe, 3 to 5 closed triangles and a variably shaped anterior field. One can distinguish five different morphotypes amongst the m1 from the Maastricht-Belvédère pit.

— morphotype 1 (Fig. 9a) is characterized by three closed triangles T1, T2 and T3 and two broadly confluent triangles T4 and T5. The anterior field consists of T6, T7 and AC 3. Morphotype 1 characterizes the European species of the genus *Pitymys*.

– morphotype 2 (Fig. 9d) is characterized by four closed triangles, a T5 which is broadly confluent with the anterior field. T6 is small, T7 well developed. This morphotype is typical of the living *Microtus oeconomus* (= *M. ratticeps*).

– morphotype 3 (Fig. 9b): The m1 of this type has five closed triangles and an anterior field with a well developed T7. T6 is incipient or absent. This type is characteristic of the living *Microtus gregalis*.

– morphotype 4 (Fig. 9f) molars have five closed triangles, a short anterior loop, well developed T6 and T7 and a deep LRA 4. The tip of LRA 4 lies in front of BRA 3. BRA 4 and LRA 5 are incipient or absent. This type is characteristic of *M. nivalis*.

– morphotype 5 molars have five closed triangles. The anterior field has well developed T6 and T7. BSA 4, LSA 5, LRA 5 and usually BRA 4 are well developed. *Microtus arvalis* and *M. agrestis* have a m1 with this type of morphology.

To quantify these differences a number of measurements have been taken. Fig. 10 shows the parameters and the way they have been measured. The relation between the parameters b and f is visible in Fig. 11.

Fig. 11 shows a larger cluster including all morphotypes except for the two specimens which lie in the left lower corner of the diagram. The latter two have been determined as *M. gregalis*.

Within the large cluster there is a higher concentration of observations in its right-lower part, and another less clear concentration in the left upper part. The specimens from Belvédère 3 are concentrated in the right-lower part of the larger cluster. They are determined as *M. arvalis* and/or *M. agrestis*.

The observations from the Belvédère 4 specimens are clearly divided between the two concentrations in the cluster: the specimens in the right-lower part, determined as *M. arvalis* and/or *M. agrestis*, and the three specimens in the left-upper part, determined as *M. oeconomus*.

The lower m1 of Belvédère 5, within the larger cluster, can be devided in two concentrations. One in the left-upper part (specimen with morphotype 2, determined as *M. oeconomus*) and another in the right-lower part (specimens with morphotype 4 and 5). However the subdivision is not clear enough and taking into account the other characters it is decided to determine all *Microtus* molars as *M. oeconomus* (see also the remarks under *M. oeconomus*).

The morphologies of the M3, m2 and m3 of the different *Pitymys* and *Microtus* species are very similar. The presence of more than one species of one of these or both genera in the different faunas makes a specific determination of these molars impossible. Therefore, they will be described as *Pitymys* sp or *Microtus* sp. in Belvédère 4, representing both genera, or as *Microtus* sp. in Belvédère 3 in which only the presence of *Microtus* sp. is indicated sofar. However, an exception can be made for those M2, which have an extra postero-lingual triangle. They are determined as *M. agrestis*. The M1 of *M. agrestis* may or may not have this extra triangle.

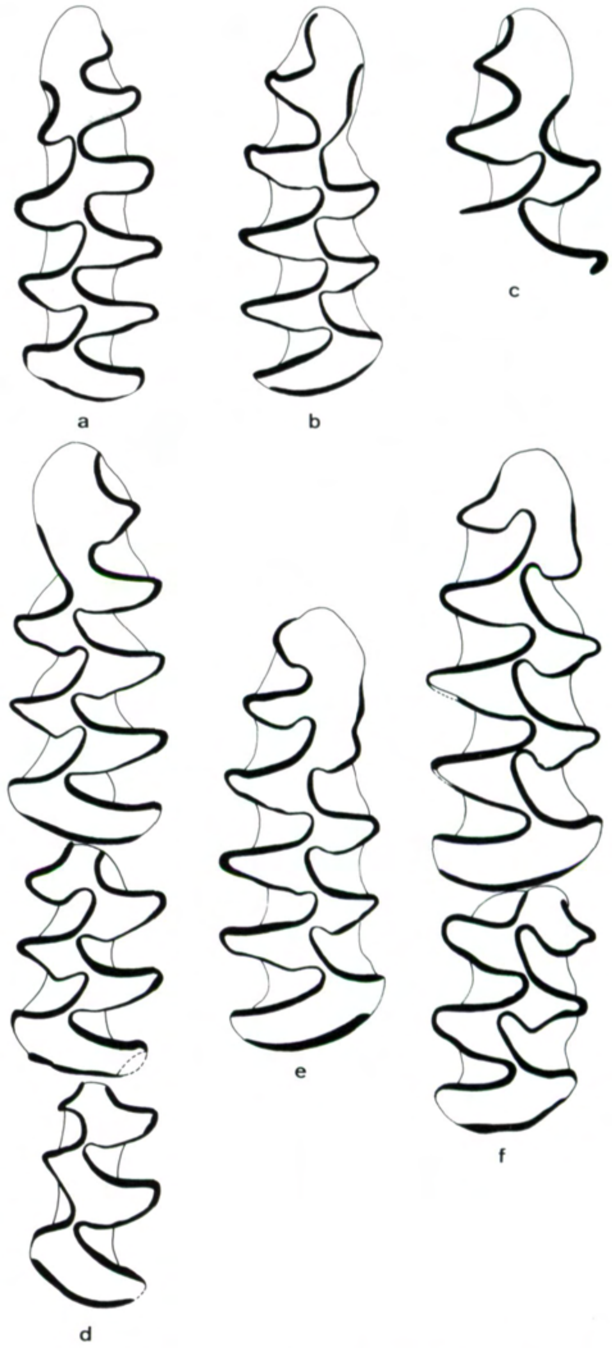

Fig. 9. a: *Pitymys* cf. *subterraneus:* m1 sin. (BL 6-475); b: *Microtus gregalis:* m1 dext. (BZ 1-451); c - f: *Microtus oeconomus* (= *M. ratticeps*): c: m1 dext. (BL 8-409); d: m1-m3 sin. (BWG 542); e: m1 dext. (BWG 521); f: m1 and m2 dext. (BWG 531). Enlargement of all the figures about 20 x.

Pitymys cf. *subterraneus* (de Sélys Long-champs, 1836)
(Pine vole)
(Fig. 9a)

Fauna; Belvédère 4
Material: m1 sin.
Measurements: L = 2.51, W = 0.90, a = 1.35, b = 0.03, c = 0.17, d = 0.19, e = 0.69, f = 0.19.

Description and remarks

The most remarkable character of this specimen is the broadly confluent triangles T4 and T5. The triangles T1 and T3 have an antero-posteriorly compressed appearance. The salient angles BSA 3 and LSA 4 have a rounded outline. The small size of the molar and its occlusal pattern are characteristic of *Pitymys subterraneus*.

Microtus gregalis (Pallas, 1779)
(Narrow-skulled vole)
(Fig. 9b)

Fauna; Belvédère 3
Material: m1 dext. (Fig. 9b)
Measurements: L = 2.45, W = 0.81, a = 1.35, b = 0.02, c = 0.02, d = 0.19, e = 0.52, f = 0.06

Fauna; Belvédère 5
Material: m1 (broken)
Measurements: W = 0.84, b = 0.02, c = 0.04, d = 0.20, e = 0.54, f = 0.10

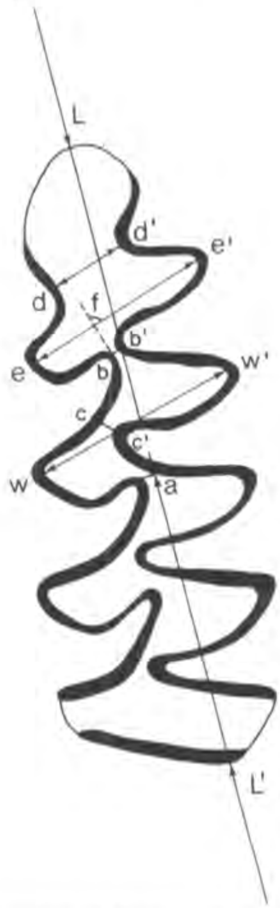

Fig. 10. Occlusal surface of *Microtus* m1 sin. illustrating the parameters that were measured. L-L' = L; W-W' = W; a-L = a; b-b' = b; c-c' = c; d-d' = d; e-e' = e, e-f = f.

Description and remarks
The juvenile specimen from Belvédère 5 consists of an anterior part only. Both molars have an incipient BRA 4. This type of morphology is characteristic of *M. gregalis*.

Microtus oeconomus (Keyserling et Blasius, 1841)
(= *M. ratticeps*)
(Root vole)
(Fig. 9c-f)

Fauna; Belvédère 4
Material: 2 m1 dext., 1 m1 sin. (Fig. 9c)
Measurements:

	L	W	a	b	c	d	e	f
N	–	2	2	3	2	3	3	3
Min.	–	0.87	1.19	0.18	0.02	0.33	0.52	0.06
Max.	–	0.93	1.23	0.20	0.04	0.45	0.61	0.14
$\bar{x}$	–	0.90	1.21	0.19	0.03	0.41	0.56	0.09

Description and remarks
The three specimens are incomplete. Their morphology corresponds to morphotype 2 characterized by a high b-value, a low c-value and by the absence or presence of an incipient T6. Except for the juvenile molars they have a wide anterior field (d = 0.44 and 0.45 respectively). The size and the morphology of these specimen are similar to the m1 of *M. oeconomus*.

Fauna; Belvédère 5
Material: 2 M1 dext., M1 sin., 2 M2 dext., 2 M2 sin., 2 M3 sin., mandibula with m1 and m2 dext., mandibula with m1-m3 sin., 11 m1 dext., 7 m1 sin., 5 m2 dext., m2 sin., m3 dext., 3 m3 sin.

Measurements:

m1	L	W	a	b	c	d	e	f
N	14	17	16	16	16	14	17	16
Min.	2.50	0.84	1.26	0.02	0.02	0.20	0.54	0.02
Max.	3.13	1.05	1.56	0.25	0.05	0.46	0.78	0.29
$\bar{x}$	2.78	0.95	1.41	0.13	0.04	0.38	0.67	0.14
SD	14.96	4.93	7.06	7.77	0.97	7.78	6.20	7.75

		N	Min.	Max.	$\bar{x}$
M1	length	1	–	–	2.18
	width	1	–	–	1.23
M2	length	3	1.48	1.79	1.62
	width	4	0.79	1.11	0.91
M3	length	–	–	–	–
	width	1	–	–	1.01
m2	length	7	1.48	1.64	1.55
	width	3	0.85	1.03	0.98
m3	length	3	1.39	1.44	1.41
	width	4	0.76	0.93	0.84

Description and remarks
The m1 molars have a variable shaped anterior part representing the morphotypes 2, 4 and 5 characteristic of *M. oeconomus, M. nivalis* and *M. arvalis/M. agrestis* respectively (Fig. 9, c-f). The anterior cap of the morphotype 5 molars is shorter than those of *M. arvalis* and *Microtus agrestis* from Belvédère 3 and 4. The variability causes the large standard deviation of most of the parameters. Fig. 11 shows that a subdivision of the different types based on the parameters b and f can hardly be made. The other parameters give the same results.

The m1 of Late Pleistocene and living *M. oeconomus* from Poland shows the same variability in the pattern (Nadachowski, 1982).

Microtus agrestis Linnaeus, 1971
(Short-tailed vole)

Fauna; Belvédère 4
Material: 2 M1 dext., 2 M1 sin., 6 M2 dext., 8 M2 sin.

Measurements:

		N	Min.	Max.	$\bar{x}$
M1	length	3	2.20	2.23	2.21
	width	4	1.02	1.19	1.11
M2	length	11	1.20	1.74	1.55
	width	14	0.71	1.09	0.96

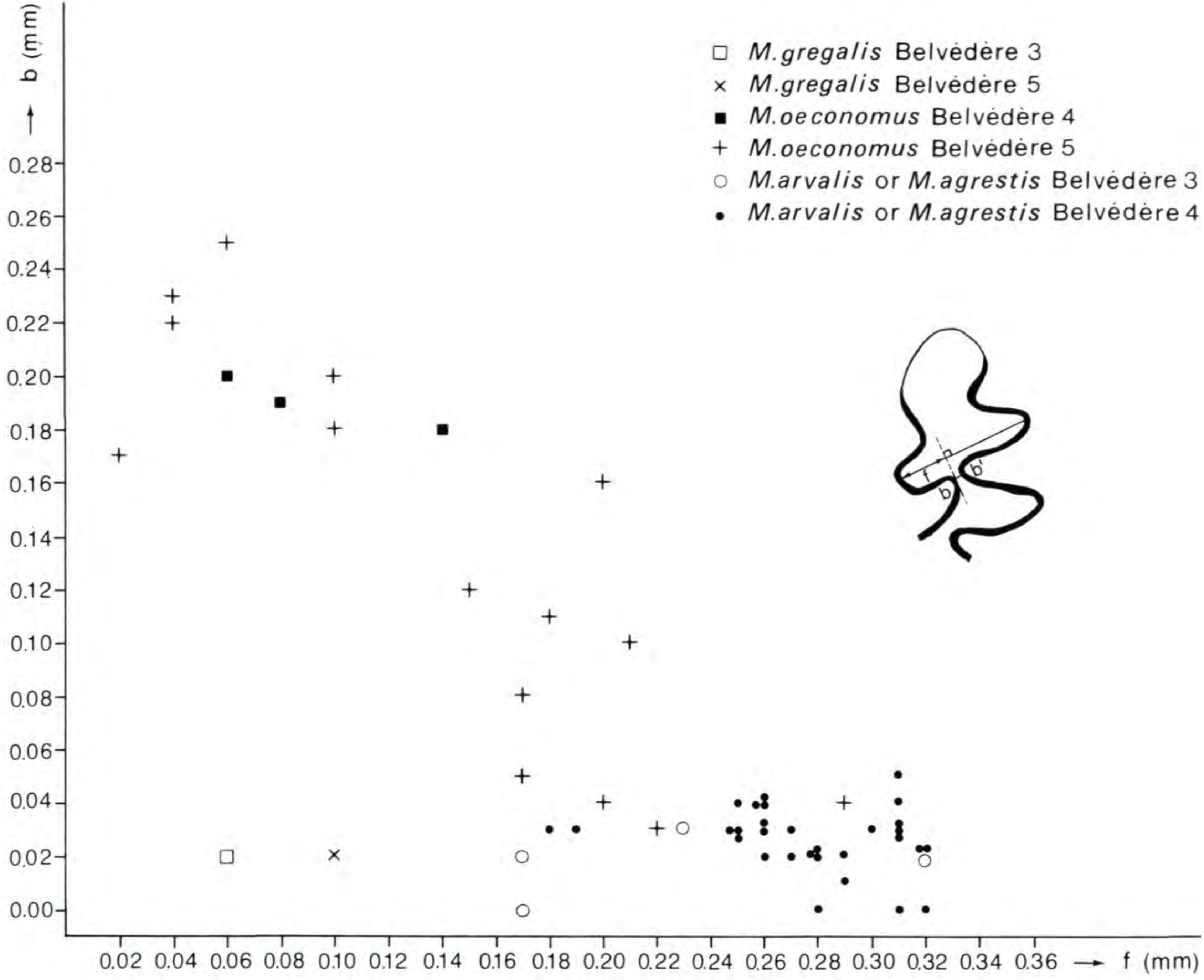

Fig. 11. Relation between b and f for the m1 assemblages of *Microtus* from Belvédère 3-5.

Description and remarks

The morphology of the M2 of the living *M. agrestis* differs from the morphology of the M2 of other *Microtus* species by having an extra small salient angle on their postero-lingual side. This extra salient angle may also be present in M1; If present its size is variable. Some M1 have a well developed one, others a very smalle one.

About half of the M2 molars (14 out of 29) of *Microtus* from Belvédère 4 belong to *M. agrestis*. Only 4 out of 28 M1 molars have an extra salient angle. The feature is absent in the 5 M1 and 2 M2 from Belvédère 3 and the 3M1 and 4 M2 from Belvédère 5.

Microtus arvalis and/or *M. agrestis*
(Short-tailed vole and/or common vole)

Fauna; Belvédère 3
Material: mandibula with m1 and m2 dext., 4 m1 dext., 1 m1 sin.

Measurements:
m1

	L	W	a	b	c	d	e	f
N	3	4	3	4	4	4	4	4
Min.	2.37	0.88	1.21	0	0.03	0.20	0.61	0.17
Max.	2.91	0.98	1.58	0.03	0.07	0.33	0.84	0.32
x̄	2.61	0.93	1.37	0.02	0.06	0.26	0.55	0.22

m2: length: 1.52, width 0.98. mm

Fauna; Belvédère 4
Material: 22 m1 dext., 18 m1 sin.

Measurements:
m1

	L	W	a	b	c	d	e	f
N	16	27	26	29	28	29	29	29
Min.	2.25	0.77	1.17	0	0	0.11	0.60	0.18
Max.	3.04	1.03	1.50	0.05	0.05	0.34	0.82	0.32
x̄	2.54	0.90	1.32	0.03	0.03	0.23	0.75	0.28

Description and remarks

All m1 have the typical arvalid morphology with five closed triangles and well developed T6 and T7 (morphotype 5). The anterior field has a variable shape mainly caused by the variation in the development of the BRA 4. Also the depth of LRA 5 and the development of BSA 5 and LSA 6 is variable.

This type of morphology is characteristic of the living species *M. agrestis* and *M. arvalis*. The morphology of the M2 shows that both species are represented in Belvédère 4. The presence of *M. agrestis* in Belvédère 3 has not been indicated sofar.

Pitymys/Microtus sp.

Fauna; Belvédère 4
Material: 13 M1 dext., 11 M1 sin., 12 M2 dext., 3 M2 sin., 2 M1/2, 12 M3 dext., 17 M3 sin., 17 m2 dext., 22 m2 sin., 12 m3 dext., 12 m3 sin.

Remarks

The molars have a morphology which is characteristic and similar for many species of the genera *Pitymys* and *Microtus*, both represented in Belvédère 4. Therefore a specific determination of these molars is impossible.

The morphology of the M3 is very variable. Most of the specimen have 3 lingual salient angles, others have 4. BSA3 is well developed, BSA 4 incipient or absent. It is difficult to distinguish the M3 of *Pitymys*, which are diagnostic for some of the species of this genus, from the M3 of *Microtus*. Therefore, all M3 from this fauna are described as *Pitymys/Microtus* sp.

Microtus sp.

Fauna; Belvédère 3
Material: 4 M1 dext., M1 sin., 2 M2 dext., 3 M2 sin., 4 M1/2, 3 M3 dext., 3 M3 sin., m1 dext., 3 m2 dext., 4 m2 sin., 8 m1/m2, 6 m3 dext., 5 m3 sin.

Remarks

The remarks applying to the material described as *Pitymys/Microtus* sp. are partly valid for material determined as *Microtus* sp. The genus *Pitymys* is excluded because it has not been indicated in Belvédère 3 sofar.

4.4.3.5. Muridae

The terminology and the measurements are according to Van der Weerd, 1976.

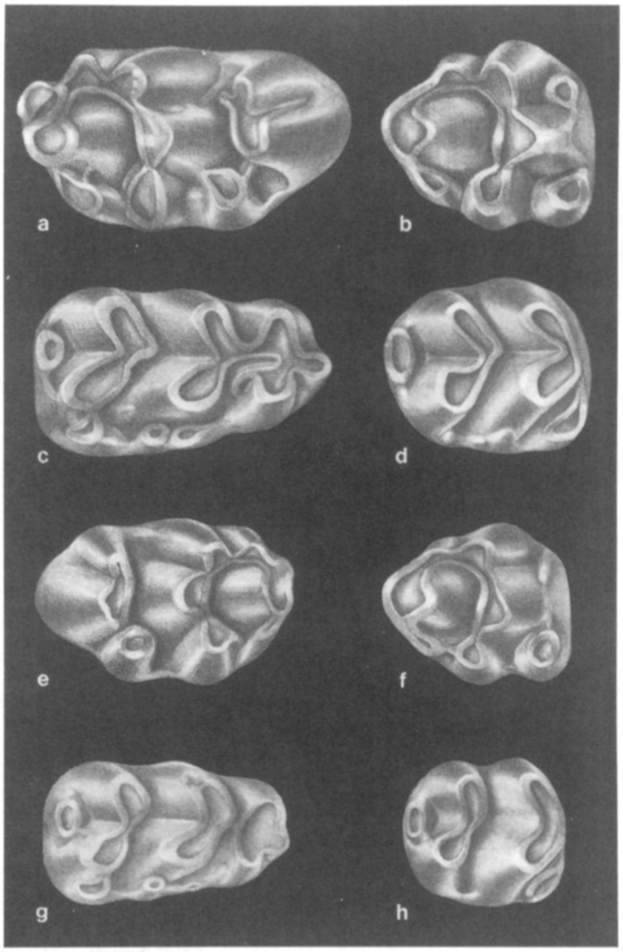

Fig. 12. a-d: *Apodemus sylvaticus:* a: M1 dext. (BL 7-603); b: M2 dext. (BL 6-605); c: m1 dext. (BL 6-615); d: m2 dext. (BL 6-624); e-h: *Apodemus maastrichtiensis* n. sp.: e M1 sin. (BL 7-701); f: M2 dext. (BL 6-703); g: m1 dext. (BL 6-731); h: m2 dext. (BL6-718). Enlargement 20 x.

Apodemus sylvaticus Linnaeus, 1758
(Wood mouse)
(Fig. 12a-d)

Fauna; Belvédère 3
Material: 2 M1 dext., 1 M2 dext., 1 M2 sin., 1 M3 sin.*, 2 m1 dext., 1 m1 sin., 1 m2 dext., 1 m3 sin.*

Measurements:

		N	Min.	Max.	x̄
M1	length	2	1.89	1.96	1.93
	width	2	1.19	1.21	1.20
M2	length	2	1.12	1.28	1.20
	width	2	1.11	1.16	1.14
M3	length	1	–	–	0.91
	width	1	–	–	0.82
m1	length	3	1.79	1.88	1.84
	width	3	1.04	1.12	1.08
m2	length	1	–	–	1.19
	width	1	–	–	0.99
m3	length	1	–	–	0.92
	width	1	–	–	0.77

* These molars belong to *A. sylvaticus* or to *A. maastrichtiensis* n. sp.

Fauna: Belvédère 4
Material: 9 M1 dext., 6 M1 sin., 6 M1 dext., 5 M2 sin., 3 M3 dext.*, 8 M3 sin.*, 5 m1 dext., 9 m1 sin., 8 m2 dext., 8 m2 sin., 12 m3 dext.*, 4 m3 sin.*

Measurements:

		N	Min.	Max.	x̄
M1	length	14	1.79	2.04	1.93
	width	14	1.12	1.28	1.19
M2	length	11	1.15	1.39	1.26
	width	11	1.06	1.22	1.13
M3	length	11	0.79	0.95	0.84
	width	11	0.73	0.91	0.82
m1	length	13	1.69	1.91	1.80
	width	13	0.94	1.15	1.05
m2	length	16	1.14	1.27	1.21
	width	16	1.00	1.18	1.10
m3	length	16	0.81	1.07	0.95
	width	16	0.75	0.92	0.86

Description and remarks

The variation in the morphology of the molars corresponds to that of the molars of *A. sylvaticus* described by Pasquier, 1974. Determination as *A. flavicollis,* of which the molars closely resemble those of *A. sylvaticus,* has been excluded because of the presence of a well developed t9 in nearly all the M2 from the Belvédère. The size of the molars of both *A. flavocollis* and *A. sylvaticus* varies considerably during the Pleistocene. The specimens from the Belvédère are smaller than those from the late Middle Pleistocene sites Le Lazaret, Orgnac and Prince Grimaldi (Pasquier, 1974).

The *A. sylvaticus* molars from Rhenen, except for the M1, are about the same size as those from Belvédère. The M1 from Rhenen are smaller (Van Kolfschoten, 1981).

The separation of *A. sylvaticus* and *A. maastrichtiensis* n. sp. in the Belvédère material is dealt with in the following section.

Apodemus maastrichtiensis n. sp.

Holotype: m1 dext. coll.nr. BL6-731 (Fig. 12g)
Paratype: M1 sin., coll.nr. BL7-701 (Fig. 12e)
M2 dext. coll.nr. BL6-703 (Fig. 12f)
m2 dext. coll.nr. BL6-718 (Fig. 12h)
Etymology: named after the town Maastricht in which the site Belvédère is situated
Type locality: Maastricht-Belvédère, Unit 4
Stratigraphic range: Middle Pleistocene
Other localities from which this species is known: Fransche Kamp, Wageningen (The Netherlands) and Miesenheim (Western Germany).

Diagnosis: a small to middle sized *Apodemus.* The M1 with 3 or 4 roots (most of them have 3) a t9 which is smaller than the t6 and a narrow, elongated t7. The t3 of the M2 is incipient or absent, t7 and t9 are small. The slopes of the cusps of m1 and m2 are more or less vertical and the angle formed by the chevrons is large. The anterior part of m1 is isolated in most of the specimen. The antero-labial cusp of m2 is small.

Differential diagnosis

A. maastrichtiensis n. sp. differs from all other *Apodemus* species in the high steepness of the slopes of the cusps in its lower molars.

Remarks on differences between *A. maastrichtiensis* n. sp. and other species of the genus *Apodemus.*

A. maastrichtiensis n. sp. differs from *A. sylvaticus* because of its smaller size (see Fig. 13) and by the development of t7 and t9 in the upper molars M1 and M2. These tubercles are better developed in the molars of *A. sylvaticus.* The t3 which is incipient or absent in the M2 of *A. maastrichtiensis* n. sp. is much larger in the second upper molar of *A. sylvaticus.* The lower molars of *A. sylvaticus* have cusps with less steep slopes and the angle formed by the chevrons is smaller.

A. maastrichtiensis n. sp. differs from *A. microps* in the size of the t3 of M2 which is better developed in *A. microps.* Only a small number of specimen of *A. microps* (2 out of 114) show a reduction of the t3 (Steiner, in Niethammer & Krapp, 1978). The t9 of M1 and M2 of *A. microps* are also larger than those of *A maastrichtiensis* n. sp.. The position of the cusps of the lower molars of *A. microps* corresponds much better to that of the lower molars of *A. sylvaticus.*

A. agrarius has a M2 without a t3. In this character there is resemblance with some of the molars of *A. maastrichtiensis* n. sp. However, *A. agrarius* differs in the morphology of the other molars. The t7 of M1 and M2 is well developed. There are no accessory cusps on the labial cingulum of m1. The m2 of *A. agrarius* is longer and has an extra cusp labial to the hypoconid.

The molars of *A. mystacinus* are much larger and more complicated with a large number of accessory cusps in m1 and m2 (see Niethammer & Krapp, 1978).

The Pliocene *A. jeanteti* is much larger than *A. maastrichtiensis* n. sp. (length M1 2.15-2.75, Pasquier, 1974).

A. occitanus and *A. dominans* are larger than *A. maastrichtiensis* n. sp. The morphology of the molars of *A. occitanus* and *A. dominans* resemble more

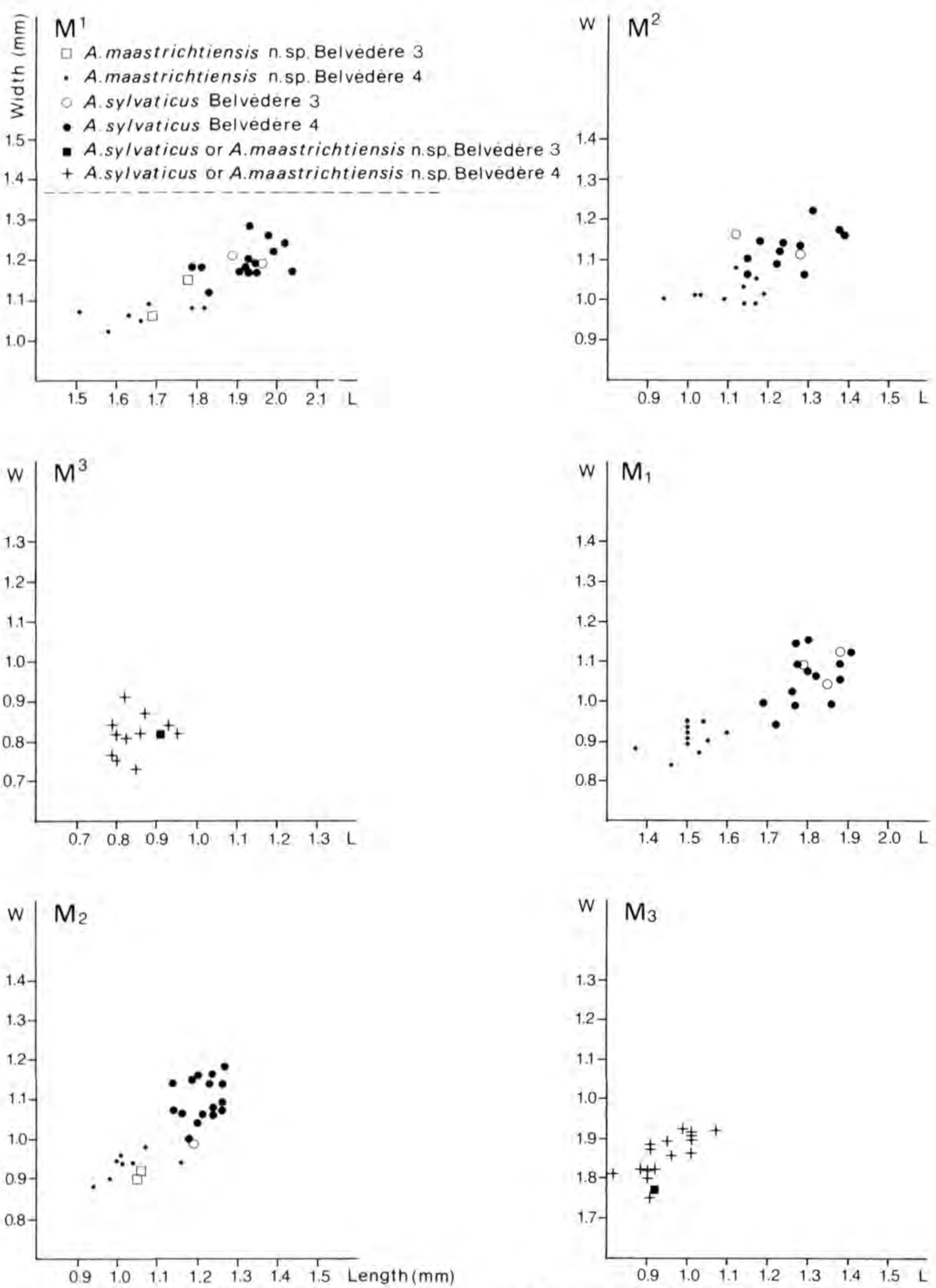

Fig. 13. Length-width scatter diagrams of molars of *Apodemus sylvaticus* and *Apodemus maastrichtiensis* n. sp. from the faunas Belvédère 3 and 4.

those of *A. sylvaticus,* for instance by having better developed t7 and t9 at the upper molars M1 and M2.

Micromys minutus, the Harvest mouse, differs from *A. maastrichtiensis* n. sp. by having a m1 with 3 roots (a diagnostic character according to Böhme in Niethammer & Krapp, 1978). The t7 of M1 and M2 of *M. minutus* is well developed, t9 is smaller than the t6 in the living species. The fossil ones show a better developed t9 (Van de Weerd, 1979). Labial accessory cusps are absent in the lower molars of *M. minutus* (Böhme, in Niethammer & Krapp, 1978). *M. minutus* is also smaller than *A. maastrichtiensis* (length M1 1.3-1.5 mm (N = 205) (Storch et al., 1973).

Fauna; Belvédère 3
Material: 1 M1 dext., 1 M1 sin., 2 m2 dext.

Measurements:

		N	Min.	Max.	$\bar{x}$
M1	length	2	1.69	1.78	1.74
	width	2	1.06	1.15	1.10
m2	length	2	1.05	1.06	1.06
	width	2	0.90	0.92	0.91

Fauna; Belvédère 4
Material: 3 M1 dext., 4 M1 sin., 7 M2 dext., 3 M2 sin., 10 m1 dext., 1 m1 sin., 6 m2 dext., 2 m2 sin.,

Measurements:

		N	Min.	Max.	$\bar{x}$
M1	length	7	1.51	1.82	1.67
	width	7	1.02	1.09	1.06
M2	length	10	0.94	1.19	1.10
	width	10	0.99	1.08	1.02
m1	length	11	1.37	1.60	1.50
	width	11	0.84	0.95	0.91
m2	length	8	0.94	1.16	1.03
	width	8	0.88	0.98	0.94

Description and remarks

The M1; The position of the tubercles with regard to each other is variable to a certain extent. Also the connection between the tubercles and the presence of edges at the posterior side of for example t1 and t3 is variable. The t7 and t9 of M1 as well as M2 are small. The t3 of the M2 is absent in one specimen, in the others it is very small.

The m1 and m2 are characterized by the high steepness of the cusps.

The antero-central cusp of m1 is small. In most specimens the labial accessory cusps are small and little differentiated from the cingulum. The anterior cusps are separated from protoconid and metaconid in most of the specimens. Only very worn elements and a single unworn one show a low connection between these cusps.

The m2 has a small developed antero-labial cusp and a small terminal heel.

The M3 and m3 of *Apodemus* from Belvédère 3 and 4 show some variation in size but they do not show any diagnostic charachter to distinguish those of *A. maastrichtiensis* n. sp. from M3 and m3 of *A. sylvaticus.* Most probably the smaller ones can be assigned to *A. maastrichtiensis* n. sp. but it is hard to decide which specimens belong to *A. maastrichtiensis* n. sp. and which to *A. sylvaticus.* Therefore, M3 and m3 are not determined at specific level.

4.4.4. Carnivora

4.4.4.1. Mustelidae

Mustela cf. *nivalis* Linnaeus, 1766
(Weasel)

Fauna; Belvédère 4
Material: I2 sin., m2 dext.
Measurements: I2; antero-posterior diameter 0.88 mm
width 0.57 mm
m2; length 0.90 mm., width 0.85 mm

Description and remarks

The lower molar, m2, has only one cusp and an antero-posterior ridge on the labial part of the crown. Compared with the measurements by Hugueney (1975) of recent stoats and weasels and of fossil material from for example La Fage it is most likely that the m2 belongs to a weasel (*M. nivalis*). The upper incisor is rather large and, therefore, it cannot be excluded that this element belongs to the larger *M. erminea.*

4.4.5. Proboscidea

4.4.5.1. Elephantidae

The terminology and the measurements are according to Maglio, 1973.

Elephas antiquus Falconer and Cautley, 1845
(= *E. namadicus*)
(Straight-tusked elephant)

Fauna; Belvédère 1
Material: molar fragment

Description and remarks

Cremers (1926) mentioned a molar of *E. antiquus* collected at the base of the gravel in the Maastricht-Belvédère pit. Two molar fragments of this elephant are stored in the Natural History Museum in Maastricht. Which of these two specimens is the one mentioned by Cremers is unknown. Both have about the same characters (width ± 80 mm, height more than 140 mm, lamellar frequency 4.5-5, enamel thickness ± 3 mm.) The plates are strongly bent anteroposteriorly, the enamel strongly folded and the enamel figures are lozenge-shaped. In these characters they correspond to the molar fragments of *E. antiquus* from Rhenen (Van Kolfschoten, 1981). They differ from Late Pleistocene molars of *E. antiquus* because of their lower lamellar frequency and their thicker enamel.

Mammuthus primigenius (Blumenbach, 1799)
(Woolly mammoth)
(Fig. 14)

Fauna: Belvédère 2
Material: incomplete lower molars m2 dext. and m2 sin. (Fig. 14), isolated plate fragments

Measurements:

	m2 dext.	m2 sin.
number of plates	6	6
length	–	79 mm
width	65 mm	73 mm
height	77 mm	110 mm
lamellar frequency	7.5	9.1
enamel thickness	2.0	1.5

Fig. 14. *Mammuthus primigenius:* buccal view of m2 sin. (Br 1).

Fauna; Belvédère 5
Material: fragment of a lower molar
Measurements: lamellar frequency 9.1, enamel thickness 1.5 mm

Description and remarks
The incomplete molars and small molar fragments are poorly preserved. They have been found during the last few years since the archaeological investigations started in 1980. A large number of more complete molars were found in the Belvédère pit or surrounding pits in the Caberg terrace many years ago (Rutten, 1909, Cremers, 1925 and 1926). It is not known from which unit most of these molars were recovered.

It is hard to determine whether the lamellar frequency and the enamel thickness of the molars of Belvédère 2 differ from the molars of Belvédère 5, because of their incomplete and badly fossilized state. The differences seem to be small.

The other more complete molars, which were found many years ago, have a lamellar frequency of 7.5-10.2 and an enamel thickness of 1.35-2.2 mm. Because of these data and because of their height and width, the molars are assigned to *M. primigenius.* The low lamellar frequency and the high enamel thickness of some of the molars suggest that we are dealing with molars of the more primitive *M. armeniacus* (= *M. trogontherii*). However, less primitive molars are known from Unit 3, the lowermost deposit from which the molars might be derived. Therefore, all molars have been determined as *M. primigenius.*

Elephantidae indet.

Fauna; Belvédère 4
Material: ulna fragment

Remarks
The fragment measures: length ± 35 cm., maximal width 8 cm. Because of the few preserved morphological characters it is impossible to determine the specimen, even at generic level.

4.4.6. Perissodactyla

4.4.6.1. Equidae

The terminology is according to Eisenmann, 1979b

Equus sp
(Fig. 15)

Fauna; Belvédère 2
Material: I1 dext., I1 sin., I2 sin.

Remarks
The incisors show the normal *Equus* characters. Their size corresponds with those of the living *E. caballus.*

Fauna; Belvédère 5
Material: DP2 sin., fragm. of an upper (pre)molar, fragm. of a lower (pre)molar, humerus sin. (distal part), unciform dext., metacarpus III dext., metacarpus III dext. (incomplete), metacarpus III sin., metacarpus IV sin., anterior third phalange.

Measurements: taken according to the method proposed by Eisenmann, 1979a.

DP2	
length	42.9 mm - 43.2 mm
width	23.4 mm - 24.0 mm

HUMERUS	
width of the distal articulation facet	87.5 mm
anterior-posterior diameter of the internal distal end	101.2 mm
minimal height of the trochlea	43.0 mm

METACARPUS (dext. (complete one)-sin.) (Fig. 15)
maximal length 233-238 mm, external length 219-231 mm, diaphysal width 40.1-39.7 mm anteroposterior diameter (DAP) of the diaphysis —-30.5 mm, articular proximal width 56.0-54.7 mm, articular proximal DAP —-35.5 mm, width of the articular facet (AW) for the magnum 47.2-44.9 mm, AW for the unciform (anterior) —-14.9 mm, AW for the unciform (posterior) —-7.8 mm, supra-artical distal width 51.9-54.5 mm, articular distal width 53.8-54.2 mm, articular keel DAP —-37.8 mm, internal condyle minimal DAP —-32.1 mm, internal condyle DAP 31.4-33.7 mm.

THIRD PHALANGE	
height	35 mm
width of the articular surface	54 mm

Description and remarks
All the material except for the incomplete metacarpus, was collected at site E, during the archaeological excavation of nov-dec. 1982.

One of the milkmolars is very worn and probably has been shed. The other is less worn. The sizes of the milkmolars and of the two complete metacarpal bones indicate that they belonged to a large-medium sized heavily-built horse (withers height 145-150 cm). Comparison of the ratio-diagrams made according to the method of V. Eisenmann (1979a) show that the morphology of the metacarpals corresponds best with those from Chatillon St Jean (Saalian?) assigned to *Equus* aff. *steinheimensis* (V. Eisenmann, pers. comm., 1985). The horse from Solutré (Weichselian) is less slender.

It is hard to determine the fossil horse material from Belvédère 2 and 5 at specific level because of the taxonomic problems concerning the Middle and Late Pleistocene Equidae and because of the small number

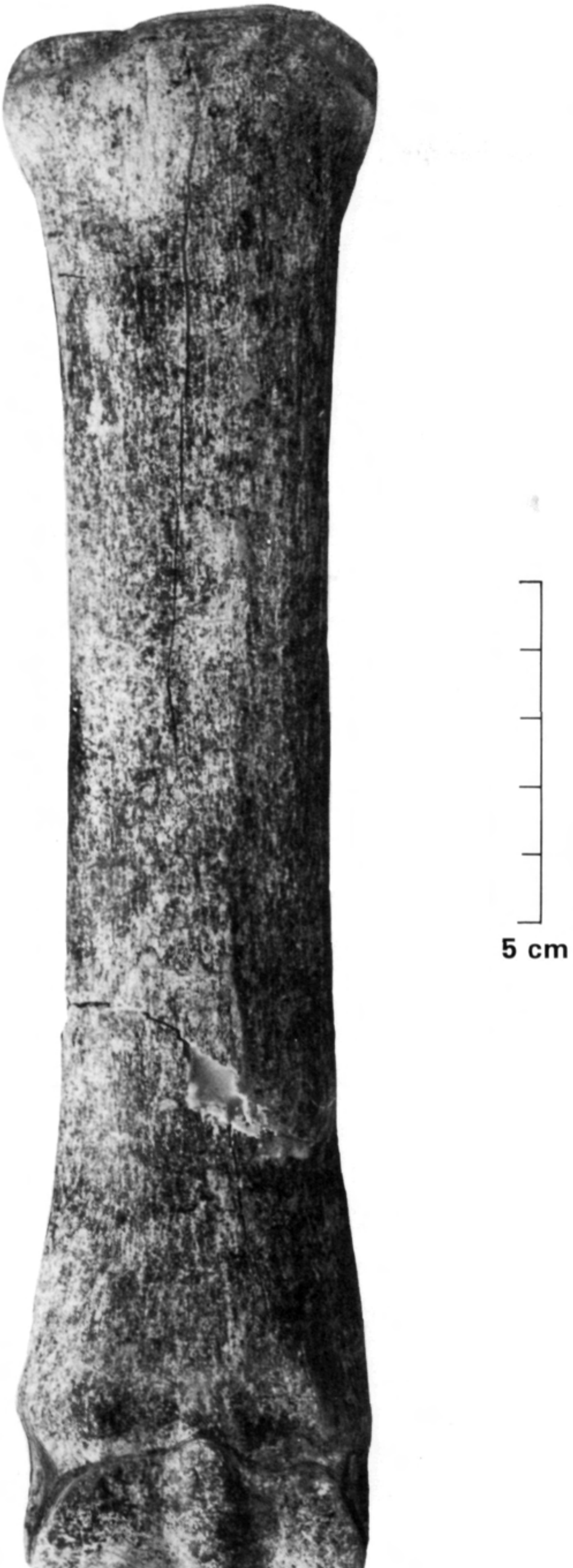

Fig. 15. *Equus* sp.: metacarpus sin. (BWG 838), anterior view.

of specimens. Therefore, the material is described as *Equus* sp.

A very remarkable specimen is an incomplete metacarpus, broken at both ends. Because of the diameter of the diaphysis (36.5 mm) it is thought that it represents a metacarpus of a young individual. There is an oval shaped hole (min. diameter 6.5 mm, max. diameter 8.0 mm) on the posterior side of the diaphysis at about 80 mm from the proximal end of the bone. The hole is situated where the foramen nutricium should be present. It has an orientation that points to the proximal end of the bone.

A large number of fossil remains of horse is collected from the deposits of the Caberg terrace many years ago. The lithostratigraphic position of some specimens has been recorded, showing that many of these fossils most probably derived from the base of Unit 6. Most of the material belongs to a large caballine type of horse. In 1923, a nearly complete tooth row (p3-m3 dext.) and five upper incisors were found in the pit called 'the Waal'. These fossils belonged to a much smaller horse. The (pre)molars have a stenonine type of morphology. The long vestibular groove of the molars penetrates the so-called doubleknot very deeply, nearly touching the V-shaped margin of the double-knot. These characters and the size indicate that most probably this represents remains of *E. hydruntinus* (V. Eisenmann, pers. comm., 1985). The same type is also known from Rhenen (described as *Equus* spec. b, Van Kolfschoten, 1981) and from the North Sea (Hooijer, 1984 and 1985). The material will be described in another article (Van Kolfschoten, in prep.).

4.4.6.2. Rhinocerotidae

The terminology and the measurements are according to Guérin, 1980.

Dicerorhinus hemitoechus (Falconer, 1868)
(Steppe rhinoceros)
(Fig. 16a-b)

Fauna; Belvédère 4
Unit: 4
Material: DP2 and DP3 sin., 8 upper (pre)molar fragments

Measurements:

DP2;	length at the base of the crown	31.5 mm
	width at the base of the crown	37.3 mm
DP3;	length at the base of the crown	41.5 mm
	width at the base of the crown	40.5 mm

Unit: 5.2.
Material: humerus

Description and remarks

The two milk-molars (Fig. 16a and b), found at site C (square m.Hz-7), fit together very well and have the same state of wear. The enamel is very thin. The profiles of the ectolophs of the milk-molars are undulated like those of *D. hemitoechus* from Lunel-Viel (Guérin, 1980). The size of the molars corresponds to the milkmolars of *D. hemitoechus*.

Some of the fragments have thicker enamel. In view of this, and because of their size it is thought that we are dealing with fragments of upper (pre)molars. The profiles of the ectoloph fragments show a

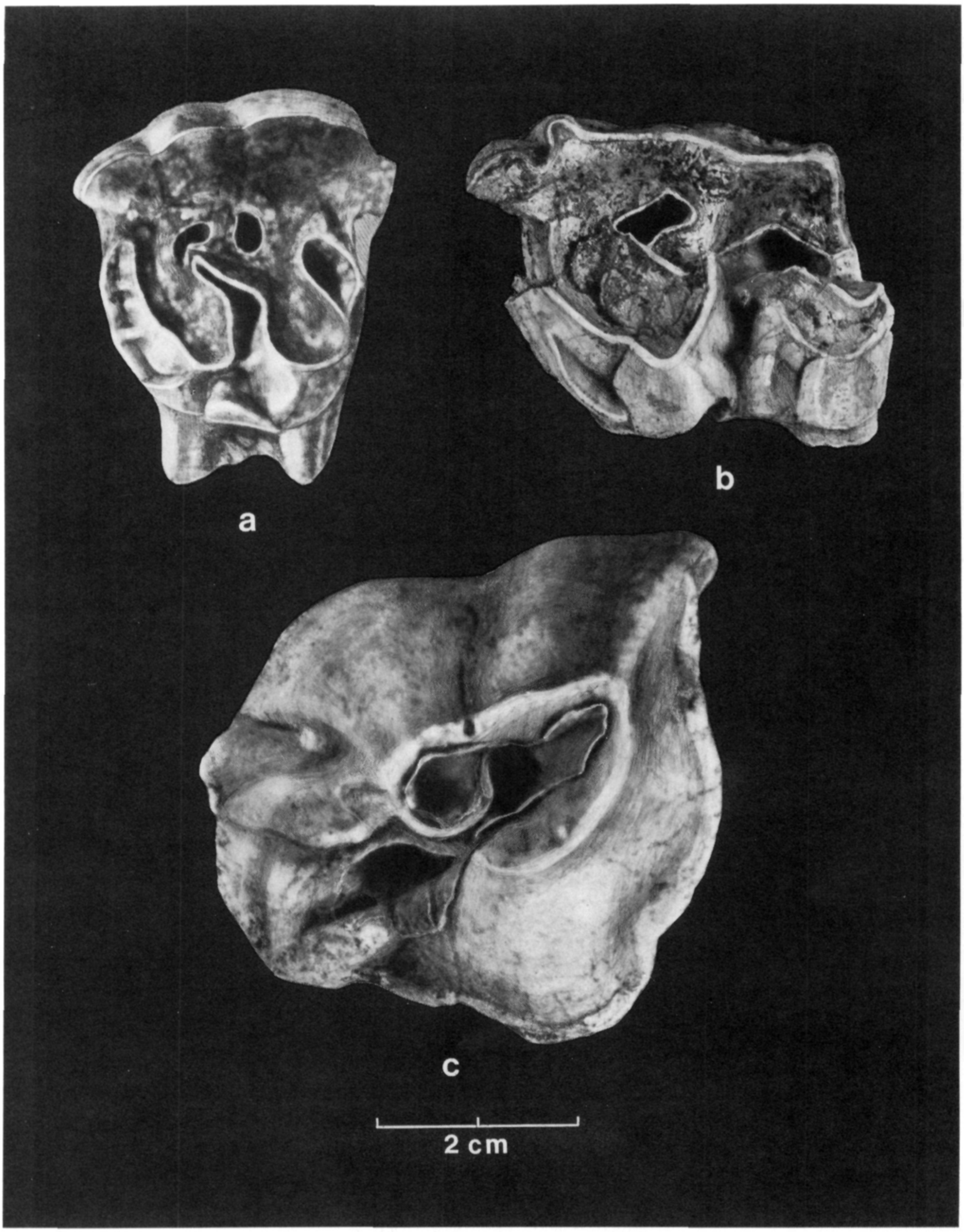

Fig. 16. a-b: *Dicerorhinus hemitoechus:* a: occlusal view of DP2 sin.; b: occlusal view of DP3 sin.; c: *Coelodonta antiquitatis:* occlusal view of M3 dext. (BWG 861).

strong undulation which is characteristic for the upper (pre)molars of *D. hemitoechus* (Guérin, 1980).

The humerus found at site B (Unit 5.2) is poorly preserved. The compressed remains have the size and the shape of a humerus of a rhinoceros.

Coelodonta antiquitatis (Blumenbach, 1799)
(Woolly rhinoceros)
(Fig. 16c)

Fauna; Belvédère 2
Material: incomplete skull

Description and remarks
In the summer of 1984 an amateur collector (R. Schönlau) found bone fragments of a skull of a rhinoceros at the top of Unit 3. The fragments partly fit together. The skull is incomplete and the dental elements are missing. The bony septum nasale indicates that this is a skull of the woolly rhinoceros (*Coelodonta antiquitatis*).

A number of (pre)molars of *C. antiquitatis* were found in the Caberg terrace many years ago. These are stored in the Natural History Museum at Maastricht and R.G.M. at Leiden. Among the fossils there is a piece of an upper jaw with M1-M3 dext. The molars are cemented with very coarse gravel most probably from Unit 3. The M3 has a triangular outline indicating a post Saalian age (Guérin, 1980). More primitive M3, of Saalian age, should have a more rectangular outline, according to Guérin (1970 and 1980). Among the M3 molars found at Rhenen there are specimens with a rectangular outline but there is also one molar with a triangular outline. These molars are found in deposits which have been displaced by the Saalian ice-sheet. This indicates that the triangular shape of the M3 of *Coelodonta antiquitatis* does not provide conclusive evidence for a post Saalian age.

The outline of the M3 resembles that of the M3 molars of *C. antiquitatis* from Belvédère 5.

Fauna; Belvédère 5
Material: skull fragments, M3 dext. (Fig. 16c), M3 sin., ectoloph of an upper (pre)molar.

Measurements: M3

length	53.7-54.7 mm
width	55.5-56.2 mm
height	70.0-71.5 mm

All the material was collected at site E. Most of the skull fragments are eroded and do not fit together. The unworn molars were found very close to each other and to the skull fragments. Both molars and the skull fragments probably belonged to one young individual.

The molars have an undulated ectoloph, a triangular outline without a posterior valley and a closed medifossette (Fig. 16). One molar has a large basal pillar at the entrance of the lingual valley.

4.4.7. Artiodactyla

4.4.7.1. Cervidae

The terminology and the measurements are according to Heintz, 1970.

Cervus elaphus Linnaeus, 1758
(Red deer)
(Fig. 17a-b)

Fauna; Belvédère 2
Material: antler fragment
Measurements: minimal diameter of the burr; 52 mm.

Description:
The shed antler has within a short distance of the burr a brow tine and a bez tine. Both tines and the beam are incomplete.

Fauna; Belvédère 4
Site; B
Material: dp4 sin., m1 sin., m3 sin. (incomplete), astragalus, distal epiphysis of a metapodial.

Measurements:
dp4: length 28.3 mm., width at the base of the crown 12.0 mm.
m1 : length 25.9 mm., width at the base of the crown 14.3 mm.
m3 : length 25-30 mm., width –

Astragalus:	lateral length	56.8 mm.
	medial length	53.6 mm.
	proximal width	36.4 mm.
	distal width	34.3 mm.
	ant.-post. diam. at the medial side	30.2 mm.
	ant.-post. diam. at the lateral side	31.2 mm.

Description and remarks
The dp4 is slightly worn, the m1 unworn (see Fig. 17a-b). The m1 has a small extostylid and a well developed cingulum at the anterior-labial side. The size of the material indicates that it belonged to a rather large red deer.

The state of wear of the dp4 and the m1 show that we are dealing with a red deer which was about half year old (Eygenraam en Pieters, 1964). The not fully grown distal epiphysis of a metapodial might have belonged to the same young individue. As artifacts were found at the same site, there might be a relation between human activity and the presence of the remains of a young red deer. If this is inferred, it is most likely that man visited the site during the end of autumn or the beginning of winter, half a year after the birth-time of red deer.

Fauna; Belvédère 5
Site; E
Material: antler fragment, radius dext. (prox. part)

Measurements:

radius;	proximal width	65 mm.
	prox. width of the articulation surface	62 mm.
	ant.-post. diameter of the articulation surface	33 mm.

Description and remarks
The antler fragment has a rugged surface and does not show any further particular characters. The size and other morphological characters of the radius fragment corresponds with radii of the living *C. elaphus*. It is too large for assignment to *Rangifer tarandus* and too small for *C. (Megaceros) giganteus*.

Cervus (Megaceros) giganteus (Blumenbach, 1803)
(Giant deer)
(Fig. 17c-d)

Fauna; Belvédère 4
Material: incomplete skull with P3-M3 sin., tibia

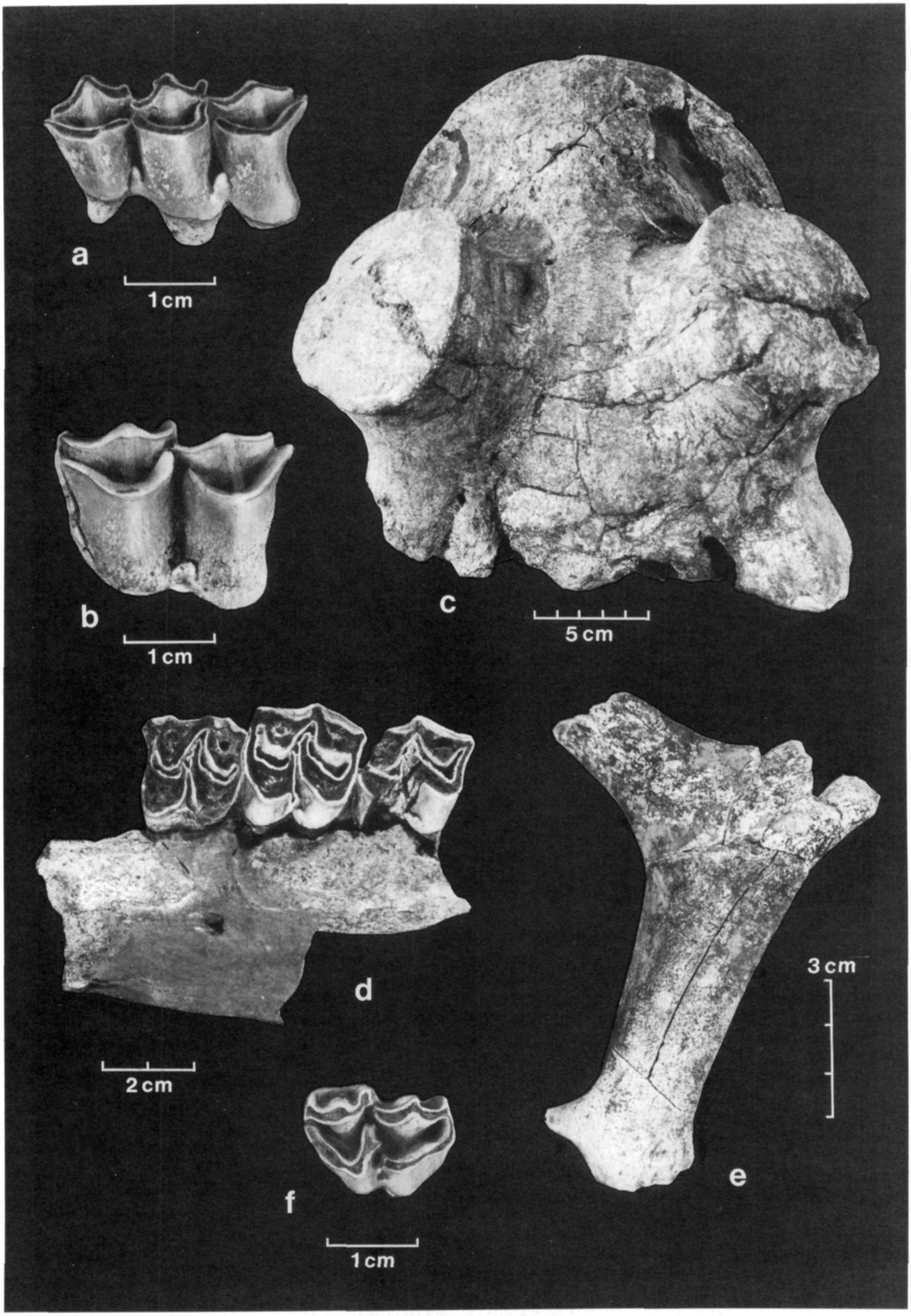

Fig. 17. a-b: *Cervus elaphus:* a: dp4 sin.; b: m1 sin.; c-d: *Cervus (M) giganteus.* c: posterior part of the skull (dorsal view); d: the anterior part of the skull with M1-M3 (ventral view); e-f: *Rangifer tarandus:* e: antler fragment. dext. (BWG 921) f: DP3 dext. (BWG 922).

Measurements:
skull; estimated length of the skull more than 60 cm.
maximal diameter of the burr 103 mm.

	P3	P4	M1	M2	M3
length	19.5	17.3	25.5	28.3	–
width	21.5	28.5	28.7	30.3	±34

Remarks

The skull was found near site B in a very fragmentary state. The state of wear of the dentition shows that we are dealing with a skull of a rather old individual (Fig. 17c). The antler was shed. The maximal diameter of the burr suggests a huge antler (Fig. 17d). The estimated length of the skull indicates a very large giant deer.

The tibia, found at site C, is badly fossilized. Its length is about 41 cm., the minimal diameter of the diaphysis about 3 cm.

Rangifer tarandus (Linnaeus, 1758)
(Reindeer)
(Fig. 17e-f)

Fauna; Belvédère 5
Material: (found at site E) dext. antler fragment, DP3 dext., fragm. metacarpus, fragment metatarsus

Measurements:

antler:	max. diameter of the burr	32.2 mm
	min. diameter of the burr	26.2 mm
	distance between burr and first tine	68.0 mm

DP3 length 16.0 mm, width 12.0 mm

Description and remarks

The antler consists of a proximal shed fragment (Fig. 19a). It has an oval shaped cross-section, a smooth surface, and a small developed brow tine. Because of its size it most probably represents an antler of a young individual. The DP3 (Fig. 19b) is slightly worn. Its morphology of the DP3 corresponds with a DP3 of the living *R. tarandus* in many characters, but differs by having a less developed metacone, an U shaped trench between paracone and parastyle (instead of a V shaped trench) and a less deep trench between metacone and metastyle. The hypocone of the milkmolar from the Belvédère is too small to assign the specimen to *C. elaphus.*

The two bones are very fragmentary. Their morphology corresponds to the living reindeer.

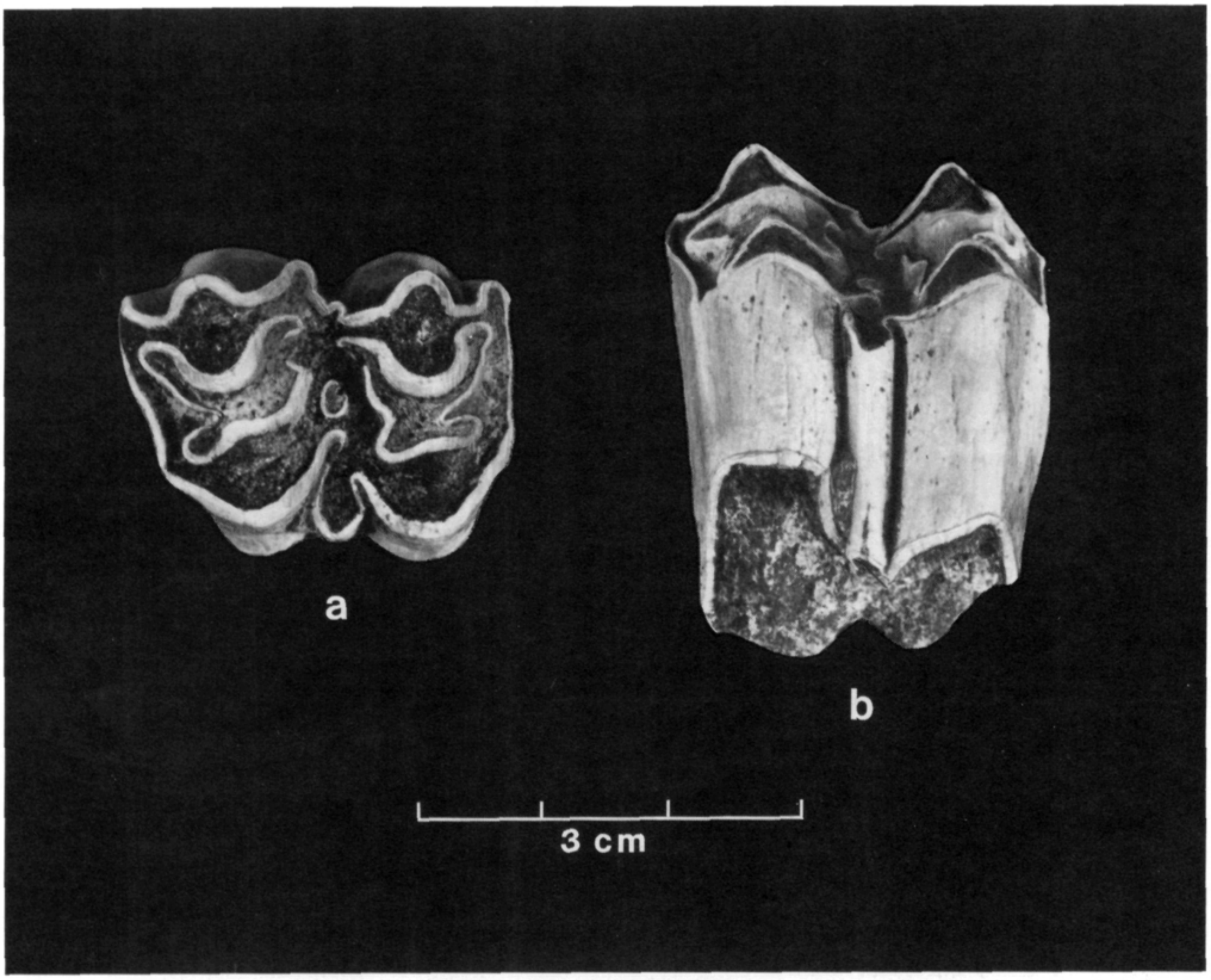

Fig. 18. *Bos primigenius/Bison priscus:* M1/2 dext. (BWG 951); a: occlusal view; b: buccal view.

Rutten (1909) placed the late-glacial reindeer from The Netherlands and Northern Europe in a new subspecies *R. tarandus diluvii,* characterized by a very small or absent brow tine.

Cremers (1927) described a skull fragment with part of an antler from the Belvédère pit. The specimen has a small brow tine, similar to the specimen from Belvédère 5 (Fig. 17e). However, according to Degerbøl and Krog (1959) a small brow tine is not characteristic of the Danish population as stated by Rutten (1909). They say that the brow tine is small in some Danish antlers, but often is very large and palmated. Since 1909 these types have also been found in The Netherlands.

Capreolus capreolus Linnaeus, 1758
(Roe deer)

Fauna; Belvédère 4
Material: dp2 dext., m1/m2 sin. (prox. part of the molar), fragment of a lower molar

Measurements: dp2 length 7.0 mm width 4.5 mm
m1/m2 length — width 8.6 mm

Description and remarks

The dp2 has a well developed parastylid and it differs in this respect from the dp2 of a recent roe deer in the collection of the I.V.A.U. Its morphology resembles that of the dp2 of a Holocene roedeer from the peat of Burwell Fen (England) figured by Reynolds, 1931. Because of this and because of its size all the material listed above has been determined as *Capreolus capreolus.*

The dp2 molar is very slightly worn, indicating that the young animal died or lost its milk molar shortly after June, the period in which roe deer usually are born. The worn m1/m2 fragment found at site B, belonged to an older individual.

Cervidae indet
(large cervid)

Fauna; Belvédère 5
Material: lingual part of an upper molar

Measurements: length 19 mm, height of the crown 25 mm

Remarks

The lingual part of a low-crowned upper molar indicates the presence of a large deer with the size of a giant deer (*Cervus (Megaceros) giganteus*) in the fauna Belvédère 5.

4.4.7.2. Bovidae

Bos primigenius/Bison priscus
(Aurochs/Bison)
(Fig. 18)

Fauna; Belvédère 5
Material: M1/2 dext.
Measurements: length 31.8 mm, width 26.0 mm, height 40 mm.

Remarks

The size of the high crowned molar corresponds with the upper molars of *Bos primigenius* and *Bison priscus.* It is most probable that it represents a molar of *Bison priscus* because the habitat of *Bison priscus* corresponds better with the environmental indications of the other species of the fauna from Belvédère 5.

5. PALAEOECOLOGY AND AGE OF THE BELVÉDÈRE FAUNAS

In this chapter the composition, palaeoecology and age of the faunas Belvédère 1-4 will first be discussed together. Belvédère 5 is treated at the end of the chapter. The habitat preferences of the living species referred to are according to Van den Brink (1978), Niethammer and Krapp (1978) and Corbet (1978).

5.1. COMPOSITION OF BELVÉDÈRE 1-4

The total number of specimens and the minimum number of individuals are given behind the species name. Relative frequencies of the species are given for the smaller mammal associations only. This frequency is based on the number of dental elements.

Fauna; Belvédère 1

	number of specimen	min. N. of indiv.
Elephas antiquus	1	1
(*Hippopotamus* sp)		

The molar of the straight-tusk elephant, *Elephas antiquus,* was found in 1926 in the Belvédère pit at the base of Unit 3 (Cremers, 1926). Probably from the same stratigraphical level are the remains of *Hippopotamus* sp. found in 1816 in the Caberg terrace at the place where Fort Willem I was built. These remains are mentioned by Habets (1887) and have been lost for many years (Rutten, 1909).

Fauna; Belvédère 2

	number of specimen	min. N. of indiv.
Mammuthus primigenius	2	2
Equus sp.	3	1
Coelodonta antiquitatis	1	1
Cervus elaphus	1	1

Fauna; Belvédère 3

Leuciscus cephalus				
Chondrostoma nasus				
Talpa europaea	5	2.86%	1	3.45%
Sorex araneus	4	3.81%	1	3.45%
Neomys fodiens	3	2.86%	2	6.90%
Ochotona pusilla	1	0.95%	1	3.45%
Spermophilus cf. *undulatus*	2	1.90%	1	3.45%
Cricetus cricetus praeglacialis	1	0.95%	1	3.45%
Clethrionomys glareolus	11	10.48%	3	10.34%
Arvicola cantiana/terrestris	12	11.43%	3	10.34%
Microtus gregalis	1	0.95%	1	3.45%
Microtus arvalis and/or *Microtus agrestis*	6	5.71%	5	17.24%
Microtus sp.	47	44.76%	6	20.69%
Apodemus sylvaticus	10	9.52%	2	6.90%
Apodemus maastrichtiensis n. sp.	4	3.81%	2	6.90%
	105	99,99%	29	100.01%

The faunal list of Belvédère 3 consists of smaller mammal species only. Undeterminable larger mammal fossils, consisting largely of bone fragments, have been collected from the base of Unit 4. There is a nearly complete vertebra similar in size to that of a red deer.

Fauna; Belvédère 4

Leuciscus cephalus
Chondrostoma nasus
Esox lucius
Emys orbicularis

	number of specimen		min. N. of indiv.	
Anatidae indet.	1		1	
Erinaceus cf. *davidi*	1	0.16%	1	0.84%
Talpa europaea	56	7.99%	5	4.20%
Sorex araneus	72	11.29%	9	7.56%
Sorex minutus	23	3.61%	4	3.36%
Neomys fodiens	18	2.82%	4	3.36%
Crocidura cf. *leucodon*	1	0.16%	1	0.84%
Eliomys quercinus	1	0.16%	1	0.84%
Clethrionomys glareolus	122	19.12%	16	13.45%
Arvicola cantiana/terrestris	28	4.39%	5	4.20%
Pitymys cf. *subterraneus*	1	0.16%	1	0.84%
Microtus oeconomus	3	0.47%	2	1.68%
Microtus agrestis	18	2.82%	8	6.72%
Microtus arvalis and/or *Microtus agrestis*	38	5.96%	21	17.65%
Pitymys/Microtus sp.	132	20.96%	22	18.49%
Apodemus sylvaticus	93	14.58%	9	7.56%
Apodemus maastrichtiensis n. sp.	36	5.64%	10	8.40%
	638	100.02%	118	99.99%
Mustela cf. *nivalis*	2		1	
Elephantidae indet.	1		1	
Dicerorhinus hemitoechus	10		1	
Cervus elaphus	5		1	
Cervus (Megaceros) giganteus	2		1	
Capreolus capreolus	3		1	

5.2. THE PALAEOENVIRONMENTAL AND PALAEOCLIMATOLOGICAL INTERPRETATION OF BELVÉDÈRE 1-4

Fauna 1

The records of *Elephas antiquus* from other sites in Northwestern Europe show that this species was associated with temperate forests. *Hippopotamus* probably preferred a subtropical-temperate climate and an area with rivers and lakes bordered by grassland.

Fauna 2

Mammuthus primigenius and *Coelodonta antiquitatis* are known to prefer a cold climate and open areas (tundra and steppe). *Equus* also prefers open areas but a warmer climate. Nowadays *Cervus elaphus* lives in woods of the temperate zone although there are populations in Scotland which are adapted to live in open areas on the highlands (Van den Brink, 1978). In the light of its present distribution the co-occurrence in Belvédère 2 of *Cervus elaphus* and *Mammuthus primigenius, Coelodonta antiquitatis* and *Equus* is remarkable. *C. elaphus* is, however, often found in association with these species for example in the fauna Belvédère 5 and the fauna from Ariendorf (Turner in Bosinski et al., 1983). The cold stage occurrences of *C. elaphus* in treeless steppe tundra vegetational conditions may be indicative of the absence of heavy snowfalls (Stuart, 1982).

Fauna 3

The species of fauna 3 indicate various habitats. The fish and the water shrew *Neomys fodiens* are tied to water. If *Arvicola cantiana/terrestris* preferred the same habitat as the living water vole *A. terrestris,* which is most likely, it is also associated with water. A steppe-environment is indicated by the steppe pika *Ochotona pusilla,* the ground squirrel *Spermophilus* cf. *undulatus,* the hamster *Cricetus cricetus praeglacialis* and the narrow skulled vole *Microtus gregalis. M. gregalis* occurs both in wooded steppe and in a tundra environment. *Microtus arvalis* and *M. agrestis* are widely distributed in Europe. The habitat of *M. arvalis* is open country such as pastureland. *M. agrestis* prefers moist areas such as high rough pastures and peat-moors, and lives also in the temperate forests and taiga of Europe. The bank vole *Clethrionomys glareolus* is indicative of the presence of woods for it mainly inhabits deciduous woods. The wood mouse *Apodemus sylvaticus* is not restricted only to deciduous woodland. It mainly inhabits open country and fringes of woods. The mole *Talpa europaea* and the common shrew *Sorex araneus* have a wide range of habitats.

The presence of *Microtus* and *Apodemus,* and the absence of lemmings lead us to the conclusion that the climate at the time was temperate. The presence of steppe-elements seems to indicate rather dry conditions away from the river in which the sediments were deposited. Along its banks the forest may have grown, the presence of which is indicated by the combination of *Clethrionomys glareolus* and *Apodemus sylvaticus.*

Fauna 4

The faunas Belvédère 3 and 4 are different in a number of aspects. The most conspicuous difference is the absence of the steppe-elements in Belvédère 4. Instead, there is a greater number of species which indicate a more humid environment.

The European pond tortoise *Emys orbicularis* inhabits ponds, lakes and rivers with still or slow flowing water. The presence of this species is indicative for a rather warm climate. A mean July temperature exceeding 17-18 C° combined with a considerable amount of sunshine with few damp, cloudy or rainy days seem to be necessary for the eggs to hatch (Stuart, 1982). The northern limit of its breeding range in Northwestern Europe is situated south of the Netherlands. More eastwards in Central Europe it reaches a higher latitude (Stuart, 1982). Occasionally the European pond tortoise occurs in The Netherlands and it is very unlikely that this only represents animals introduced by man.

The presence of the European pond tortoise gives evidence that the mean summer temperature during deposition of Unit 4b was about the same or, more likely, exceeded that of the present day.

Hedgehogs, like *Erinaceus europaeus* live in dry areas of the deciduous and mediterranean woodland zones and inhabit for instance fringes of woods just as the bicoloured shrew *Crocidura leucodon.* The pygmy shrew *Sorex minutus* occurs in the same habitat but also in more humid areas. *Eliomys quercinus* inhabits deciduous and mixed forests. It is widely distributed in the southern part of Western Europe up to the southern part of The Netherlands. The European pine vole *Pitymys subterraneus* lives in rather humid open areas in the temperate forest zone and more eastwards in the steppe zone.

The larger mammals also indicate the presence of deciduous woods and open country areas. The weasel *Mustela nivalis* occurs in areas with forests and high ground covering vegetation. *Dicerorhinus hemitoechus.* and *Cervus (M) giganteus,* the giant deer, were living in an open environment. *Cervus elaphus* nowadays prefers a temperate climate and a wooded habitat but is very adaptive as noted above. The roe deer *Capreolus capreolus* is associated with forests.

The environment as indicated by Belvédère 4 seems to have consisted of grasslands and forests. The absence of steppe representatives indicates that the climatic conditions are like those of today, perhaps somewhat warmer because of the presence of *Emys orbicularis.*

5.3. THE ENVIRONMENTAL CHANGES AT THE STADIAL-INTERSTADIAL TRANSITION

The lower part of the fluviatile sediments consists of coarse gravel, in the upper part of which only larger mammal remains have been found. In the overlying Units 4a and 4b, one can recognize a fining upwards sequence in sediment grain size. The decrease in velocity of flow, indicated by the upward change in grain size, cannot explain the difference in composition of the Belvédère 3 and 4 smaller mammal faunas. Instead, the time needed to explain these faunal differences indicates that the deposition of these fluviatile sediments cannot be attributed to a single depositional event in a short period.

The lower gravels (Unit 3) were deposited during a cold stage. The overlying mostly sandy sediments (Unit 4a) contain fauna remains which indicate a temperate continental climate. The fauna-association from the uppermost part of the fluviatile sequence indicates a more humid warm-temperate climate. These data document the palaeoecological change during the transition from the cold stadial period to a warm-temperate stage. First of all the tundra changes into an environment with mainly steppe and some woods afterwards followed by a more humid environment with forests alternated with some open areas. The data of the malacological investigation of the same traject support the ideas about the palaeoecological transition (see T. Meijer, 1985). This transition is most probably the result of climatic changes caused by changes in the atmospheric circulation (J. Oerlemans, pers. comm, 1985).

A comparable environmental sequence is indicated by the smaller mammals from the Jankovich cave in Hungary described by Kretzoi, 1957. These document the transition of the Weichselian cold stage with a tundra environment, to the Holocene with a fauna characterized by a high frequency of steppe-elements followed by a warm-temperate stage with a more humid climate and a wooded environment.

5.4. THE RELATION BETWEEN HUMAN ACTIVITY AND THE PRESENCE OF LARGER MAMMAL FOSSILS AT THE SITES B, C AND G

The faunal assemblages Belvédère 1 and 2 do not show any involvement of man. The scarce remains from these units are very fragmentary and do not show traces which are clearly caused by human beings.

Many of the artifacts and the bone fragments, collected from Unit 4a and 4b, were found isolated but there are a few clear concentrations of artifacts, molars and bone fragments (see Roebroeks, 1985). The bone material is badly preserved due to decalcification of the sediments and is in general hard to identify.

Besides bone fragments, site B yielded a humerus of a rhinoceros, a milkmolar, an astragalus and a distal epiphysis of a metapodial of a red deer and a molar fragment of a roe deer. A skull of a giant deer and remains of an European pond tortoise were found about 4 meters east of Site B. At Site C there was a concentration of artifacts, milkmolars, molar fragments and unindentifiable bone fragments of a steppe rhinoceros. Site C yielded also a tibia of a giant deer. Remains of an elephant, a rhinoceros, a red deer and a roe deer were collected at Site G, during the excavations in Nov.-Dec. 1984 and during the summer of 1985. Except for the elephant bone fragment, the material from Site G is not described in this paper.

The stage of wear of the molars of the red deer found at Site B, indicates that they belonged to an individual which died when it was about a half year old. At present red deer are usually born in June. This indicates that the one from Maastricht-Belvédère site B died at the end of autumn or during the first part of the winter. The inferred relationship between human activity and the presence of these fossils suggests that man visited the site during the end of autumn or during the beginning of the winter period. The milkmolar of the roe deer, *Capreolus capreolus,* shows that the animal died during an earlier annual period. But the relation between the presence of this molar and human activity is not clear.

5.5. THE STRATIGRAPHICAL POSITIONS OF THE FAUNA-ASSOCIATIONS

The stratigraphical position of Belvédère 1 is not clear. It is most likely that it dates from late Early Pleistocene or early Middle Pleistocene (Van Kolfschoten and Vervoort-Kerkhoff, in prep.).

The fauna of Belvédère 2 contains the woolly rhino *Coelodonta antiquitatis.* The migration of *C. antiquitatis* from Asia to Europe is supposed to have taken place during the beginning of the Saalian period (Guérin, 1980). Therefore, the maximal age of Unit 3 is considered to be Early Saalian. The biostratigraphical value of the triangular shape of the M3 of *C. antiquitatis* has been discussed above (see the systematic description of *C. antiquitatis*).

The most primitive specimen of *Mammuthus primigenius,* probably from Unit 3, suggests a Saalian or an Early Weichselian age for this unit. A Weichselian age for Unit 3 does not fit the biostratigraphical data from the overlying Units 4a and 4b.

The presence of the advanced *Arvicola terrestris* at Rhenen in sediments pushed by the Saalian ice sheet shows that *A. terrestris* replaces *A. cantiana/terrestris* before the end of the Saalian (Van Kolfschoten, 1981) and not during the Eemian as supposed by Von Koeningswald (1973). Therefore, it is evident that the faunas Belvédère 3 and 4, from the Units 4a and 4b respectively, containing *A. cantiana/terrestris,* must be dated before the end of the Saalian period. As *Coelodonta antiquitatis,* found in the underlying Unit 3, indicates a post-Holsteinian age for the studied sediments deposition of Units 4a and 4b took place during a warm-temperate interval within the Saalian. This interval might be correlated with the Hoogeveen interstadial, the first temperate interval within the Saalian (see Zagwijn, 1973). The smaller mammal fauna-association from Rhenen must date from a later interval within the Saalian (= ? Bantega-interstadial).

5.6. BIOSTRATIGRAPHICAL CORRELATION OF THE FAUNAS BELVÉDÈRE 3 AND 4 WITH OTHER MIDDLE PLEISTOCENE MAMMAL FAUNAS

The fauna-associations Belvédère 3 and 4 are characterized by;

- the presence of *Arvicola cantiana/terrestris*
- the absence of *Talpa minor, Drepanosorex* and *Trogontherium*
- the relative high frequency of *Microtus agrestis* within the *Microtus agrestis/M. arvalis* assemblage of Belvédère 4.

This fauna-association is typical for the *Arvicola cantiana/terrestris* Zone, one of the three biozones to be defined for N.W. Europe for the late Middle Pleistocene (Van Kolfschoten, in prep.). The *A. cantiana/terrestris* Zone is tentatively correlated with the Hoogeveen interstadial of the Early Saalian (see previous paragraph).

A fauna with a corresponding association has been found at Wageningen (The Netherlands) in a pit called De Fransche Kamp (Van Kolfschoten, in prep.). The fauna from Ariendorf (Western Germany) (Bosinski et al., 1983, Steensma and Van Kolfschoten, in prep.) fits also into the *Arvicola cantiana/terrestris* Zone. The fauna from Ariendorf indicates a cold stage and is therefore not chronologically equivalent to the faunas Belvédère 3 and 4 and the fauna from Wageningen.

The fauna from the Lower Travertines of Ehringsdorf (Heinrich, 1980a, 1981 a and b) corresponds to the faunas Belvédère 3 and 4 in many aspects. The steppe-elements known from Belvédère 3 are dominant in the fauna from Ehringsdorf. However, the fauna-association from Ehringsdorf includes also species of more or less moist biotopes (Heinrich, 1981b). The corresponding fauna-association supports the idea of Heinrich (1982) that the fauna from the Lower Travertines of Ehringsdorf must be correlated with an interstadial period within the Saalian.

There is also much resemblance between the fauna-association Belvédère 3 and 4 and the fauna from La Fage (Chaline, 1975, Guérin 1973, Beden & Guérin, 1975). Chaline (1975) describes the presence of *Arvicola terrestris* in the fauna from la Fage but Jánossy (1976) notes the presence of *Arvicola cantiana/terrestris* in the fauna from La Fage, Lazaret and the lower loess deposits from Achenheim. Jánossy correlates these faunas with his Castellum phase which might correspond to our *Arvicola cantiana/terrestris* Zone.

Correlation of the Units 3 and 4 from Maastricht-Belvédère with the Achenheim sequence (Heim, et al., 1982) is difficult. The first occurrence of *Coelodonta antiquitatis* and its co-occurrence with *Mammuthus primigenius* and the *Mammuthus trogontherii/primigenius* transitional type at the base of cycle II of the Achenheim sequence suggests a correlation between the deposition of this cycle and the lowermost Pleistocene deposits from Maastricht-Belvédère. Whether the remains of *Arvicola cantiana/terrestris* mentioned by Jánossy (1976) are also derived from this part of the sequence is unknown.

All the faunas which correspond to the fauna-associations Belvédère 3 and 4 should have an Early Saalian age.

There are also a number of Middle Pleistocene faunas which are considered to be older than the *A. cantiana/terrestris* faunas. These faunas are placed in the *Arvicola cantiana* Zone characterized by the evolutionary stage of *Arvicola* and the presence of *Talpa minor, Drepanosorex savini, Trogontherium cuvieri* and the absence or the occurrence in a low frequency of *Pliomys* and *Microtus agrestis.* Faunas which are correlated to the *Arvicola cantiana* zone are for instance the fauna from Neede with *Trogontherium cuvieri* (Hooijer, 1959), Bilzingsleben with *Arvicola cantiana* and *Trogontherium* (Heinrich, 1980b) and Miesenheim (Van Kolfschoten in Boscheinen et al., 1984). The fauna from Miesenheim shows all the characteristics of the *Arvicola cantiana* Zone. This Zone is tentatively correlated to the Holsteinian interglacial period.

Pre-Eemian fauna-associations with *Arvicola terrestris* postdating the fauna-association from Belvédère 3 and 4 are known from Rhenen (Van Kolfschoten, 1981) and Biache St. Vaast (Chaline, 1978). These faunas are tentatively correlated to the Bantega interstadial (see Zagwijn, 1973).

5.7. COMPOSITION OF BELVÉDÈRE 5

Fauna; Belvédère 5	number of specimen		min N. of indiv.	
Nyctea scandiaca	1			1
Talpa europaea	1			1
Spermophilus (Urocitellus) cf. *undulatus*	8	2.95%	1	1.79%
Cricetulus migratorius	1	0.37%	1	1.79%
Dicrostonyx torquatus	220	80.88%	39	69.64%
Arvicola terrestris	3	1.10%	2	3.57%
Microtus gregalis	1	0.37%	1	1.79%
Microtus oeconomus	39	14.34%	12	21.43%
	272	100.01%	56	100.01%

Mammuthus primigenius	1	1
Equus sp.	10	2
Coelodonta antiquitatis	4	1
Cervus elaphus	2	1
Rangifer tarandus	4	1
Cervidae indet. (large deer)	1	1
Bos primigenius/Bison priscus	1	1

The mammal fossils from Site E do not show any indication of being transported over a large distance. The remains of the arctic lemming are in some cases rather complete. Therefore, the fauna-association can be regarded and treated as representing a single fauna.

5.8. PALAEO-ENVIRONMENTAL AND PALAEO-CLIMATOLOGICAL INTERPRETATIONS OF THE BELVÉDÈRE 5 FAUNA-ASSOCIATION

The arctic lemming (*Dicrostonyx torquatus*), the most abundant species in this fauna is restricted to the Palaearctic tundra. It is predated by tundra birds of prey like the snowy owl (*Nyctea scandiaca*). *Talpa europaea* lives in a wide range of habitats. Open grassland or steppe environment is indicated by the ground squirrel *Spermophilus* cf. *undulatus*. The grey hamster (*Cricetulus migratorius*) is now an element of the steppe fauna. The water vole, *Arvicola terrestris,* is widely distributed in Europe and Asia. It is closely associated with water. *Microtus gregalis,* the narrow-skulled vole, occurs both in a tundra environment and in the wooded steppes. *M. oeconomus* has a wide distribution and occurs for instance in a tundra environment to the wooded parts of the steppe zone.

Mammuthus primigenius and *Coelodonta antiquitatis* are known to prefer a cold climate and open areas (tundra and steppe). *Equus* prefers a steppe biotope. *Cervus elaphus,* the red-deer, presently distributed through most of the deciduous and Mediterranean woodlands is highly adaptable as been discussed before. The reindeer, *Rangifer tarandus* is common throughout the tundras and taiga of Eurasia and North America. The large bovids *Bison priscus* and *Bos primigenius* probably did not live in the same habitat. *Bison priscus* which is often found in association with *Mammuthus primigenius* and *Coelodonta antiquitatis,* should have preferred an open environment while *Bos primigenius* probably favoured more forested habitats.

The habitats of the present species and the composition of the fauna indicate a tundra/steppe environment and a cold and rather dry climate during the period in which the fauna lived. The presence of *Cervus elaphus* could indicate the absence of heavy snowfalls (Stuart, 1982).

5.9. THE INFLUENCE OF HUMAN ACTIVITY ON THE COMPOSITION OF THE FAUNA FROM SITE E

The presence of man at site E is indicated by the flint artifacts (see Roebroeks, 1985). Except for the oval shaped hole in the metacarpal bone of a horse which might be man-made, no clear bone artifacts nor clear traces on the bone fragments, indicating human activity, have been recognized.

An indication for human involvement from the composition of the assemblage from site E is the high frequency of young individuals among the larger mammals. The molar fragment of the mammuth belonged to a young individual, just as the milkmolars of at least two horses and the milkmolar of a reindeer. Both M3 molars of the woolly rhino are unworn, found closely to each other, together with many bone fragments of a skull which might have been smashed by man before fossilization. The molar of the large bovid also belonged to a rather young individual. Not one of the determinable larger mammal remains belonged to full-grown and/or old individuals.

The frequency of young individuals over the limited area sampled at Site E (40 square meters), within the small number of specimens of larger mammals is interpreted as due to human interference with the concentration of these fossils. There are no clear indications for the period of year man visited the site. A relation between human activity and the presence of the smaller mammal remains is not assumed. These concentrations are rather due to activities of birds of prey like the snowy owl which is represented in the fauna-association.

5.10. THE STRATIGRAPHICAL POSITION OF THE FAUNA-ASSOCIATION BELVÉDÈRE 5

The fauna Belvédère 5 is derived from the base of Unit 6.2 which is situated above Soil III, correlated with the Eemian Sol de Rocourt (see Vandenberghe et al., 1985). Therefore, it applies that Belvédère 5 has a Weichselian age.

The mammuth-woolly rhino-reindeer association occurs in many Weichselian faunas and corresponds to the geological age indications. The reindeer is unknown from Saalian deposits in the Netherlands, such as the underlying gravels (unit 3) from the Belvédère locality and ice-pushed deposits in the central and northern part of The Netherlands. A pre-Weichselian occurrence in England is also very uncertain (Stuart, 1982).

The abundant fossils of the arctic lemming, *Dicrostonyx torquatus* give indications for a pre-Middle Weichselian age of the fauna (see the remarks at the description of *D. torquatus*). The presence of *A. terrestris* in ice-pushed deposits at Rhenen indicates that this species already occurs before the end of the Saalian (Van Kolfschoten, 1981). *A. terrestris* shows a general trend towards larger size during the Weichselian period but there is no uniform progression (Stuart, 1982). Despite that and despite the small number of specimens, the small length of the m1 molar from the site E assemblage may be used as an indication for an early Weichselian age of the fauna.

Also the horse remains, although not determined to specific level indicate a type of horse which is closer related to the type found at Chatillon St Jean (Saalian?) than to the horse from Solutré (late Middle Weichselian).

The presence of the reindeer, *Rangifer tarandus,* which is very abundant in Weichselian deposits in the middle of The Netherlands, suggests that the fauna from Unit 6.2 is a Weichselian one.

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THE PRE-WEICHSELIAN NON-MARINE MOLLUSCAN FAUNA FROM MAASTRICHT-BELVÉDÈRE (SOUTHERN LIMBURG, THE NETHERLANDS)

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CONTENTS

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SUMMARY

From the Belvédère pit near Maastricht (Province of Limburg) a non-marine molluscan fauna is described. The deposits in which the fauna occurs belong to lithological Unit 4 of the local stratigraphy and date from the Middle Pleistocene. Seventy-six mollusc species were found, six of them hitherto unknown for the Dutch Quaternary. The most important species are *Bithynia troscheli, Corbicula fluminalis, Spermodea lamellata,* and *Zonitoides sepultus.*

The fauna points strongly to a warm-temperate climate and can be assigned to a stage occurring between the Holsteinian and Eemian interglacials. Various sections are discussed with respect to the ecological and climatic implications of the molluscan fauna and an environmental description is given of the main archaeological horizon present in the Belvédère pit.

INTRODUCTION

At the Belvédère pit (Vandenberghe et al. 1985) molluscs have been found at two stratigraphic levels: at the base of the Middle Silt Loam (lithological Unit 6) and in the Terrace Sands (Unit 4). The latter represents the top of the Veghel Formation. The fauna present in Unit 4 is discussed in this paper; for the Unit 6 fauna the reader is referred to the paper by Kuijper (1985).

Unit 4, which is represented by three facies (Vandenberghe, 1985), is a fining-upward sequence and can be considered a continuation of the terrace gravels (Unit 3). All three facies contain molluscs, although the top of the unit has undergone leaching in some places. In dolines more calcareous tufa (Unit 4c) has escaped leaching locally.

The localities of the molluscan faunas under discussion are given in Fig. 1. Four sections were sampled in several places (Mol. 1-4). Analysis of some single samples from other places provided additional information (Mol. 5-11).

Samples were dried and then submerged in water to which some hydrogen peroxide had been added. The disintegrated sediment was sieved, using a mesh size of 0.5 mm under a flow of water from a handspray and dried in an oven at 50°C. If too much clay still remained, the procedure was repeated.

After being dried, the residue was sieved to form several size fractions. All recognizable shell material was sorted under a binocular microscope at four magnifications (6, 12, 25, and 50). For counts, only relatively complete individuals and characteristic fragments were included. Essentially, the counting procedure was according to Ložek (1964b) except for bivalves. Valves obviously belonging to one individual were counted as such, whereas all other single valves were counted individually too (cf. Sparks, 1961).

Other fossil findings concern calcitic granules of *Lumbricus* sp., several ostracod species, remains of fish and small mammals, plant casts, and oösporangians of characeae. Except for *Lumbricus* sp., these organisms were not included in the counts. Traces of predation on gastropod shells were counted separately.

All molluscan species found are listed in table 1, which also shows data on ecological classification, climate, and the like.

ECOLOGICAL CLASSIFICATION

Ecological classification was based mainly on the work of Ložek (1964b), but also on elements from other authors (e.g. Häszlein, 1977). Two series of diagrams are presented, one based on frequencies of individuals reflecting the environment prevailing in the immediate surroundings and the other based on numbers of species reflecting environmental features of a larger area.

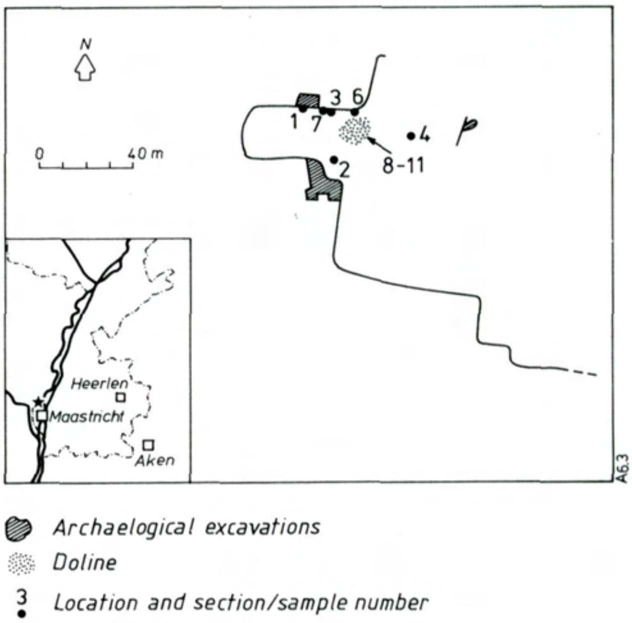


Fig. 1. Site of the Belvédère pit.

Land molluscs were classified as follows: woodland, open-ground, mesophile, and hygrophile species.

Calculation of the data and presentation in the diagrams follow Fuhrmann (1973): each ecological group is presented separately and a 'land fauna in the strict sense' is distinguished. According to this concept, hygrophile species were not included in the sum of woodland, open-ground, and mesophile species, but calculated as a percentage of all land molluscs. The forest ratio (i.e., the ratio of woodland to open-ground species) proposed by Fuhrmann is used.

Among the freshwater species, seven groups were distinguished, six of which occur in Belvédère, i.e., species of marshes (A. 1); banks and periodic waters (A. 2); stagnant, poorly vegetated waters (Klarwassersee; B. 1); stagnant, well-vegetated waters (B. 2); stagnant and moving waters (C); and moving waters (D). Furthermore, following Häszlein (l.c.), a rough subdivision was made according to substrate preference, i.e., into bottom-dwelling and vegetation-dwelling animals. The *Bithynia* ratio (Gilbertson & Hawkins, 1978) is used to detect sorting effects caused by water movement.

CLIMATIC CLASSIFICATION

Climatic classification is applied only for land molluscs. This classification is derived from recent distributions given by Kerney, Cameron and Jungbluth (1983) and is related to the grouping used by British authors (Sparks, 1961). Three main groups were distinguished:

I: Species extending north of the arctic circle. Most of these species are common on the European mainland too; only a small number have a restricted arctic (and high-alpine) distribution. The latter category is absent in Belvédère.

II: Species having a northern limit at the arctic circle or not far south of it.

III: Species reaching only to the southernmost part of Scandinavia or confined to the European mainland.

This subdivision may be too crude to cover all of the climatic features, although the related British system has proved useful. The expression of, for instance, the atlantic (oceanic) versus the continental type of climate is poor. However, only some species fit into one of these two climate types. At present, *Vertigo moulinsiana, Spermodea lamellata, Aegopinella nitidula, Clausilia bidentata,* and *Cepaea nemoralis* have a more or less atlantic distribution, whereas *Cochlicopa nitens, Vallonia enniensis, Macrogastra plicatula, Clausilia parvula,* and *Helicopsis striata* now have an approximately continental occurrence. The extinct *Zonitoides sepultus* can be considered continental too, on the basis of its fossil distribution.

REMARKS ON SOME SPECIES

Valvata piscinalis

This is one of the most abundant species. According to Häszlein (1977), *Valvata piscinalis* is a detritus feeder and can be assigned to the bottom-dwelling aquatic gastropods. With a depth optimum of 1.50-2.00 m, this species penetrates far below the vegetation zone, down to 10 m (Ökland, 1964). Its presence in vegetation-rich places can be explained by its need for shelter, since it dislikes sudden water movement (Fretter & Graham, 1978). In the recent fauna of The Netherlands it is found in all types of fresh and slightly brackish water, although lakes seem to be preferred. On these grounds, the species is classified here as lacustrine (group C), whereas British authors usually consider it as belonging to the 'running water group' (Sparks, 1961).

In The Netherlands, *Valvata piscinalis* is commonly found in interglacials and interstadials throughout the Quaternary.

Bithyniidae

In The Netherlands, *Bithynia troscheli* (*B. inflata* according to British authors) is known to occur in interglacial deposits ranging from the Tiglian through the Holsteinian (Meijer, 1974). Recently, the species was also encountered in the Schouwen deposit, which is generally considered to be of late Eemian age. Recent finds of vertebrate remains indicate, however, that at least locally the lower part of the deposit may be of Lower Quaternary age (Van Kolfschoten, pers. comm., 1985).

In Great Britain the species is present in the Ipswichian and Hoxnian interglacials (Kerney, 1977), currently correlated with the continental Eemian and Holsteinian stages. At present, the species has a distinctly Central European distribution.

Bithynia tentaculata is one of the most common freshwater species in Dutch Quaternary beds and has the same stratigraphic distribution as *Valvata piscinalis.* It is very common in the recent fauna too.

Fossil shells of bithyniids are rather scarce: untill now, *Bithynia troscheli* has even been known only from operculums in Dutch localities. Although no unbroken adult specimens could be found in Belvédère, the tiny shells occur rather frequently. Operculums of the two species are often confused, but they are definitely, different as shown by the data collected by the measurement of 200 specimens from this area (fig. 2).

The ratio of operculums to shells (*Bithynia* ratio) reflects sorting effects caused by water movements (Sparks, 1964; Gilbertson & Hawkins, 1978). Obviously, when the ratio is not 1:1 a certain degree of sorting has taken place. River deposits usually contain more operculums than shells, and in most cases there are even no shells at all. This can be explained as follows. After death of the animal the shell, made buoyant by the decaying body of the snail, tends to float on the surface of the water. After a while, the operculum becomes detached and sinks to the bottom, but the shell may continue to float and will be carried away. Thus, overrepresentation of operculums in the sediment means a net loss of shells. In the most extreme cases only operculums are left; all the shells have been carried away. In places where the river slows down and the water becomes stagnant or where there is an abundant floating vegetation, incoming floating shells can accumulate. In such places shells without the operculum outnumber the operculums of the individuals living at the site itself.

If only operculums are found it must be kept in mind that, like the internal shells of Limacidae and Milacidae, they are composed of calcite. Other shells are composed of aragonite, which is more fragile and less resistant to leaching than calcite is. In beds containing a high proportion of wood remains, the molluscan fauna may consist solely of operculums of Bithyniidae, shells of Limacidae and Milacidae, and some corroded gastropod apices. Often the molluscan fauna is then accompanied by calcitic grains of *Lumbricus* (the common earthworm) and vertebrate remains. In such cases, there are two possible interpretations: either the residual fauna is a result of transport or any initially present aragonitic shell-material has been dissolved.

The different behaviour of operculums and shells has consequences for the counts on which the diagrams of individuals are based. Since the behaviour of all gastropod shells is basically the same, it is clear that counts of *Bithynia* material must be based on the shells and not on the operculums. Therefore, it is not permissible simply to use the highest number of fragments present, which is often the number of opercu-

LIST OF SPECIES	1	2	3	4	5		1						2			
						1	2	3	4	5	6	7	1	2	3	4
FRESHWATER GASTROPODA						B	A						E	D		
Valvata cristata Müller, 1774	A.1	V			C	–	–	–	–	–	–	–	1	–	–	–
Valvata piscinalis (Müller, 1774)	C	B			A	4	1	12	533	669	284	79	70	278	399	159
Bithynia tentaculata (Linné, 1758)	C	B			D	–	–	–	–	–	–	–	1	–	–	–
B. tentaculata: opercula						–	–	–	–	–	–	–	5	–	–	1
Bithynia troscheli (Paasch, 1842)	B.2	V			A	–	–	–	2	5	8	2	8	43	80	85
B. troscheli: opercula						–	–	–	3	18	14	6	16	101	295	597
Galba truncatula (Müller, 1774)	A.2	V			A	–	–	–	3	–	–	–	8	43	36	28
Lymnaea stagnalis (Linné, 1758)	B.2	V			A	–	–	–	3	2	1	–	–	–	3	–
Lymnaea corvus (Gmelin, 1788)	B.2	V			A	–	–	–	–	–	–	–	–	–	–	2
Stagnicola palustrus (Müller, 1774)	A.1	V			A	–	–	–	–	–	–	–	–	–	–	–
L. corvus/S. palustris	A.1	V			A	1	–	–	–	1	1	1	14	11	36	16
Radix ovata (Draparnaud, 1805)	C	V			A	–	–	7	50	51	27	12	3	6	7	5
Acroloxus lacustris (Linné, 1758)	B.2	V			D	–	–	–	–	–	–	–	–	–	–	–
Ancylus fluviatilis (Müller, 1774)	D	B			A	–	–	–	–	–	1	1	–	–	–	–
Planorbis carinatus (Müller, 1774)	B.2	V			D	–	–	–	–	–	–	–	10	9	–	–
Planorbis planorbis (Linné, 1758)	A.1	V			A	–	–	–	–	1	–	1	3	7	12	38
Anisus leucostomus (Millet, 1813)	A.2	V			A	–	–	–	–	1	–	–	46	89	272	343
Anisus vortex (Linné, 1758)	B.2	V			C	–	–	–	–	–	–	–	5	24	27	58
Anisus vorticulus (Troschel, 1834)	B.2	V			C	–	–	–	–	–	–	–	12	22	11	–
Bathyomphalus contortus (Linné, 1758)	C	V			A	–	–	–	–	1	–	–	–	1	1	–
Gyraulus laevis (Alder, 1838)	B.1	V			A	–	–	6	290	127	80	34	–	–	–	–
Gyraulus crista (Linné, 1758)	B.2	V			A	–	–	–	6	5	7	2	22	210	220	53
Hippeutis complanatus (Linné, 1758)	B.2	V			C	–	–	–	–	–	–	–	3	4	6	1
Segmentina nitida (Müller, 1774)	A.1	V			E	–	–	–	–	–	–	–	1	–	–	–
Physa fontinalis (Linné, 1758)	C	V			C	–	–	–	–	–	–	–	39	79	158	97
BIVALVES																
Unionidae spec. indet.	–	B			B	–	–	–	–	–	–	–	–	–	–	–
Corbicula fluminalis (Müller, 1774)	D	B			C	–	–	–	–	–	–	–	2	7	6	1
Pisidium amnicum (Müller, 1774)	D	B			A	–	–	2	27	60	105	13	–	6	8	8
Pisidium casertanum casertanum (Poli, 1791)	C	B			D	–	–	–	–	–	–	–	–	–	16	–
Pisidium casertanum ponderosum (Stelfox, 1918)	D	B			E	–	–	–	–	–	–	–	–	–	–	–
Pisidium milium Held, 1836	B.2	B			A	–	–	–	–	1	15	–	–	5	60	19
Pisidium moitessierianum Paladilhe, 1866	D	B			A	–	–	–	4	–	–	–	–	–	–	
Pisidium nitidum Jenyns, 1832	C	B			A	–	–	2	5	6	–	48	2	43	291	49
Pisidium obtusale Pfeiffer, 1821	A.2	B			A	–	–	–	–	1	–	–	11	4	54	17
Pisidium subtruncatum Malm, 1855	C	B			A	–	–	3	28	134	261	268	42	85	418	113
Pisidium supinum Schmidt, 1850	D	B			A	–	–	–	48	71	48	27	–	5	22	1
Pisidium indet.	–	B			–	1	–	–	–	–	–	–	–	–	–	–
Sphaerium corneum (Linné, 1758)	C	B			A	2	–	1	15	59	41	76	11	59	8	33

Table 1. Distribution chart of the molluscan species found in Unit 4 of the Belvédère sequence.

Legend: * Mol. number of sections and samples; + samples; ° zonation.
Column **1:** Ecological grouping.
Al: marshes; A2: banks and periodic waters; B1: stagnant, poorly vegetated waters; B2: stagnant, well-vegetated waters; C: stagnant and moving waters; D: moving waters; W: woodland; O: open ground; M: mesophile; H: hygrophile.
Column **2:** Substrate preference of the freshwater molluscs.
V: vegetation; B: bottom.
Columns **3** and **4:** Climatic grouping.
3: I – species extending north of the arctic circle
II – species having their northern limit at or south of the arctic circle
III – species reaching only the southernmost part of Scandinavia or confined to the European mainland
4: At – atlantic (oceanic) type of climate
Co – continental type of climate
In – indifferent species
Column **5:** Molluscan zone in which the species appears in the Belvédère sequence.

2					3						4						5	6		7	8	9	10	11	•
5	6	7	8	9	1	2	3	4	5	6	1	2	3	4	5	6		I	II						+
C		B			E	D			C		E			A			D	E	D	D	E	E	E	E	°
–	–	–	–	–	1	–	1	–	1	–	181	–	–	–	–	–	–	x	–	–	13	11	15	94	
86	21	–	–	–	1203	259	250	259	1494	116	216	140	2	2	4	1	2	x	10	52	83	59	50	176	
–	–	–	–	–	3	–	2	–	–	–	75	42	–	–	–	–	6	x	25	5	87	41	55	180	
–	–	–	–	–	10	1	3	7	–	–	82	55	–	–	–	–	6	x	–	10	68	38	41	125	
55	32	–	–	–	739	122	167	114	27	3	10	6	2	–	–	–	–	x	–	29	9	4	6	15	
786	162	–	–	–	449	210	281	219	340	84	11	14	5	–	–	–	–	x	–	26	10	1	–	4	
14	1	–	–	–	39	19	27	15	2	2	1	1	–	–	–	–	–	x	–	4	1	–	4	2	
3	–	–	–	–	9	2	3	3	1	–	–	2	–	–	–	–	–	x	–	–	1	1	3	1	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	2	–	–	–	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	–	1	–	–	–	
24	9	–	–	–	214	301	239	116	4	1	18	4	–	2	–	–	–	x	–	18	4	7	5	16	
4	2	–	–	–	82	12	13	8	37	2	7	3	4	1	4	1	–	x	4	4	1	–	6	7	
–	–	–	–	–	–	2	–	1	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	
–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	1	–	–	x	–	–	–	–	–	–	
–	–	–	–	–	–	–	–	–	–	–	42	23	–	–	–	–	–	x	3	9	10	6	25	33	
45	14	–	–	–	5	42	70	78	4	1	–	–	1	–	–	–	–	x	–	3	–	–	–	–	
56	9	–	–	–	759	1877	1866	613	20	5	30	3	–	2	–	–	–	x	–	139	4	2	10	19	
2	9	–	–	–	51	61	111	95	1	–	2	–	–	–	–	–	–	–	–	4	–	–	–	1	
–	–	–	–	–	19	–	1	13	–	1	22	15	–	–	–	–	–	x	–	5	3	–	2	6	
1	–	–	–	–	7	5	–	–	1	–	2	–	–	–	–	–	–	–	–	1	–	1	1	4	
–	–	–	–	–	–	1	–	–	180	2	–	–	–	2	–	–	–	x	–	–	–	–	–	–	
2	1	–	–	–	1167	126	169	101	20	6	45	39	–	–	2	–	–	x	–	4	1	1	1	3	
2	–	–	–	–	53	47	140	43	1	1	9	–	–	–	–	–	–	x	–	–	–	–	–	1	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
9	1	–	–	–	157	190	140	101	3	1	–	2	–	–	–	–	–	x	–	–	–	–	–	–	
–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
1	–	–	–	–	37	17	28j	21j	13j	–	–	3	–	–	–	–	111	47	157	3	1j	1j	4j	–	
3	1	–	–	–	138	10	21	10	39	5	14	28	7	–	–	1	14	x	84	3	8	10	16	3	
–	–	–	–	–	37	–	4	–	–	–	12	–	–	–	–	–	–	x	–	7	3	2	1	9	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	
3	–	–	–	–	110	29	53	44	4	1	12	8	1	–	–	–	–	x	–	4	1	–	–	3	
–	–	–	–	–	–	–	–	–	–	–	–	6	–	–	–	–	–	x	–	–	1	–	–	–	
11	3	–	–	–	361	131	162	70	13	3	4	20	52	1	1	–	–	x	–	4	4	1	2	5	
3	–	–	–	–	175	85	27	12	1	–	13	–	2	–	–	–	–	x	–	4	–	1	–	5	
20	31	–	–	–	826	96	119	92	81	20	14	88	26	6	2	–	–	x	–	24	7	–	2	11	
3	1	–	–	–	61	5	7	4	69	56	–	7	11	–	1	–	–	x	–	1	2	1	–	–	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
20	8	–	–	–	82	44	26	27	77	7	6	1	23	–	–	1	–	x	–	–	–	1	–	–	

LIST OF SPECIES	**1**	**2**	**3**	**4**	**5**		1						2			
						1	2	3	4	5	6	7	1	2	3	4
LAND GASTROPODA						B	A						E	D		
Carychium cf. *mariae* Paulucci, 1878	H		III	In	C	—	—	—	—	—	—	—	134	173	278	327
Carychium tridentatum (Risso, 1826)	H		II	In	D	—	—	—	—	—	—	—	24	2	11	55
Succinea putris (Linné, 1758)	H		I	In	A	—	—	—	—	—	—	—	—	—	—	—
Succinea elegans (Risso, 1826)	H		I	In	A	—	—	—	—	—	—	—	—	—	—	—
Succinea elegans/putris	H		I	In	A	1	—	—	3	9	—	3	164	151	241	228
Succinea oblonga Draparnaud, 1801	H		III	In	A	—	—	—	—	—	1	—	—	—	—	—
Cochlicopa lubrica (Müller, 1774)	M		I	In	C	—	—	—	—	—	—	—	54	31	44	49
Cochlicopa lubricella (Porro, 1838)	O		I	In	D	—	—	—	—	—	—	—	—	—	2	—
Cochlicopa nitens (Gallenstein, 1848)	H		III	Co	D	—	—	—	—	—	—	—	—	—	—	—
Columella edentula (Draparnaud, 1805)	H		I	In	D	—	—	—	—	—	—	—	—	—	—	—
Vertigo angustior Jeffreys, 1830	H		III	In	C	—	—	—	—	—	—	—	27	4	—	—
Vertigo antivertigo (Draparnaud, 1801)	H		II	In	C	—	—	—	—	—	—	—	16	12	41	63
Vertigo moulinsiana (Dupuy, 1849)	H		III	At	C	—	—	—	—	—	—	—	30	42	107	71
Vertigo pusilla Müller, 1774	W		I	In	E	—	—	—	—	—	—	—	—	—	—	—
Vertigo pygmaea (Draparnaud, 1801)	O		II	In	D	—	—	—	—	—	—	—	6	4	3	11
Vertigo substriata (Jeffreys, 1833)	H		I	In	E	—	—	—	—	—	—	—	—	—	—	—
Pupilla muscorum (Linné, 1758)	O		I	In	A	—	—	—	11	15	8	8	—	—	1	4
Vallonia costata (Müller, 1774)	O		I	In	B	2	—	—	—	—	—	—	28	19	13	37
Vallonia enniensis (Gredler, 1856)	H		III	Co	D	—	—	—	—	—	—	—	54	36	43	22
Vallonia pulchella (Müller, 1774)	O		I	In	C	—	—	—	—	—	1	—	331	290	172	263
Spermodea lamellata (Jeffreys, 1830)	W		II	At	E	—	—	—	—	—	—	—	—	—	—	—
Acanthinula aculeata (Müller, 1774)	W		II	In	E	—	—	—	—	—	—	—	—	—	—	—
Punctum pygmaeum (Draparnaud, 1801)	M		I	In	C	—	—	—	—	—	—	—	6	15	17	15
Discus rotundatus (Müller, 1774)	W		II	In	D	—	—	—	—	—	—	—	—	—	—	—
Vitrina pellucida (Müller, 1774)	M		I	In	C	—	—	—	—	—	—	—	4	18	11	30
Vitrea contracta (Westerlund, 1871)	M		II	In	E	—	—	—	—	—	—	—	—	—	—	—
Vitrea crystallina (Müller, 1774)	W		II	In	D	—	—	—	—	—	—	—	—	—	—	1
Nesovitrea hammonis (Ström, 1765)	M		I	In	C	—	—	—	—	—	—	—	5	3	2	2
Aegopinella nitidula (Draparnaud, 1805)	W		II	At	C	—	—	—	—	—	—	—	—	—	3	3
Zonitoides nitidus (Müller, 1774)	H		I	In	C	—	—	—	—	—	—	—	49	51	55	31
Zonitoides sepultus Ložek, 1964	W		III	Co	D	—	—	—	—	—	—	—	—	—	—	—
Zonitidae, sp. indet.	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Milacidae, sp. indet.	W		III	In	D	—	—	—	—	—	—	—	1	—	5	3
Limacidae large species	W		II	In	E	—	—	—	—	—	—	—	—	—	—	—
Limacidae small species	M		I	In	A	—	—	—	2	—	3	3	65	83	160	238
Deroceras agreste (Linné, 1758)	O		I	In	A	—	—	—	—	—	1	—	—	—	—	—
Euconulus fulvus (Müller, 1774)	M		I	In	C	—	—	—	—	—	—	—	54	61	90	93
Clausilia bidentata (Ström, 1765)	W		I	At	E	—	—	—	—	—	—	—	—	—	—	—
Clausilia parvula Férussac, 1807	M		III	Co	A	—	—	—	—	1	—	—	2	4	6	3
Macrogastra plicatula (Draparnaud, 1801)	W		II	Co	E	—	—	—	—	—	—	—	—	—	—	—
Clausiliidae, sp. indet.	—		—	—	D	—	—	—	—	—	—	—	—	—	—	—
Helicopsis striata (Müller, 1774)	O		III	Co	A	—	—	—	—	—	—	1	—	—	—	—
Trichia hispida (Linné, 1758)	M		I	In	A	2	—	1	7	7	7	5	103	69	175	263
Arianta arbustorum (Linné, 1758)	W		I	In	C	—	—	—	—	—	—	—	9	10	16	15
Cepaea nemoralis (Linné, 1758)	W		III	At	B	1	—	—	—	—	—	—	13	14	11	4
Arianta/Cepaea	W		—	—	D	—	—	—	—	—	—	—	—	—	—	—

2					3						4						5	6		7	8	9	10	11	•
5	6	7	8	9	1	2	3	4	5	6	1	2	3	4	5	6		I	II						+
C		B			E	D			C		E			A			D	E	D	D	E	E	E	E	°
7	34	–	–	–	901	959	1280	626	18	4	143	1	–	–	–	–	1	x	–	63	10	2	4	58	
–	–	–	–	–	–	–	–	–	–	–	68	8	–	–	–	–	–	x	–	–	2	3	5	16	
–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	
64	15	–	–	–	185	100	165	100	17	5	22	3	1	–	–	–	–	x	–	6	3	1	–	15	
–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	x	–	2	–	–	1	1	
9	2	–	–	–	78	134	139	73	8	4	20	1	–	–	–	–	–	x	–	17	1	1	3	9	
–	–	–	–	–	–	–	–	16	–	–	–	–	–	–	–	–	–	x	–	–	–	–	1	–	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	2	–	
–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	x	–	–	–	–	–	–	
–	–	–	–	–	20	5	3	3	–	1	30	5	–	–	–	–	–	x	–	5	16	9	17	29	
18	–	–	–	–	91	364	264	141	7	3	9	1	–	–	–	–	1	x	–	21	7	6	27	14	
20	4	–	–	–	169	100	200	45	2	–	1	3	–	–	–	–	–	x	–	9	1	1	4	4	
–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	2	
–	–	–	–	–	56	19	35	49	–	–	–	–	–	–	–	–	–	x	–	3	–	–	–	11	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	1	2	
–	–	–	–	–	10	2	3	3	16	5	–	2	5	2	1	–	–	x	–	–	5	8	14	1	
–	–	–	–	–	11	5	12	5	–	–	76	16	–	–	–	–	–	x	–	2	18	9	3	33	
–	–	–	–	–	375	170	164	82	–	–	16	–	–	–	–	–	–	x	–	14	7	10	7	25	
44	9	–	–	–	561	385	597	337	27	8	10	7	–	–	–	–	–	x	–	36	7	7	4	17	
–	–	–	–	–	–	–	–	–	–	–	2	1	–	–	–	–	–	x	–	–	2	–	–	2	
–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1	1	–	
4	–	–	–	–	95	33	48	31	5	1	28	6	–	–	–	–	–	x	–	3	4	–	3	–	
–	–	–	–	–	–	–	1	–	–	–	7	1	–	–	–	–	–	x	–	–	–	–	2	2	
12	4	–	–	–	32	15	27	28	6	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	
–	–	–	–	–	1	–	–	–	–	–	5	4	–	–	–	–	–	x	–	–	2	–	1	6	
–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	x	–	–	–	–	–	–	
1	–	–	–	–	2	–	2	1	–	–	5	–	–	–	–	–	–	x	–	–	7	5	3	6	
3	1	–	–	–	4	–	1	–	–	–	14	1	–	–	–	–	–	x	–	5	2	–	4	27	
18	3	–	–	–	110	116	138	56	6	1	18	2	–	–	–	–	–	x	–	4	23	14	15	25	
–	–	–	–	–	–	–	–	4	–	–	2	–	–	–	–	–	–	x	–	–	2	–	–	–	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	1	3	–	–	
–	–	–	–	–	1	1	–	–	–	–	10	3	–	–	–	–	–	x	–	–	–	–	–	–	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	
85	8	–	–	–	140	146	177	105	13	1	13	5	1	–	–	–	–	x	–	4	1	1	1	4	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
23	2	–	–	–	105	169	186	88	4	3	8	2	–	–	–	–	–	x	–	5	1	1	3	2	
–	–	–	–	–	1	–	–	–	–	–	31	3	–	–	–	–	–	x	–	–	6	8	11	23	
1	1	–	–	–	5	5	7	5	–	–	1	–	–	–	–	–	–	x	–	1	3	8	–		
–	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	x	–	–	–	–	1	3	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	
–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	
88	24	–	–	–	82	110	174	129	24	7	10	3	2	1	1	1	–	x	1	12	5	3	6	11	
2	1	–	–	–	23	8	10	13	1	1	3	1	1	–	–	–	–	x	18	1	1	–	1	8	
–	–	–	–	–	16	6	4	6	–	1	10	3	1	–	–	–	–	x	7	1	4	5	4	2	
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	

lums. Instead, the second highest number of fragments, e.g. of apices, must be used. This leads ultimately to absence of the species in the counts for the diagrams of individuals if only operculums are found. In such cases *Bithynia* has been included in the counts for the diagrams of species.

In the Belvédère deposits a curious thing has happened to many operculums: they are broken, but the fragments are cemented firmly together. The operculum has a crumpled appearance. The same is seen for some Limacidae shells, but never for other shell material. Many of the thin-walled larger gastropods are found to be completely preserved although crushed in the sediment, but cementation was never observed. Crushing can be ascribed to post-depositional movements in the sediment.

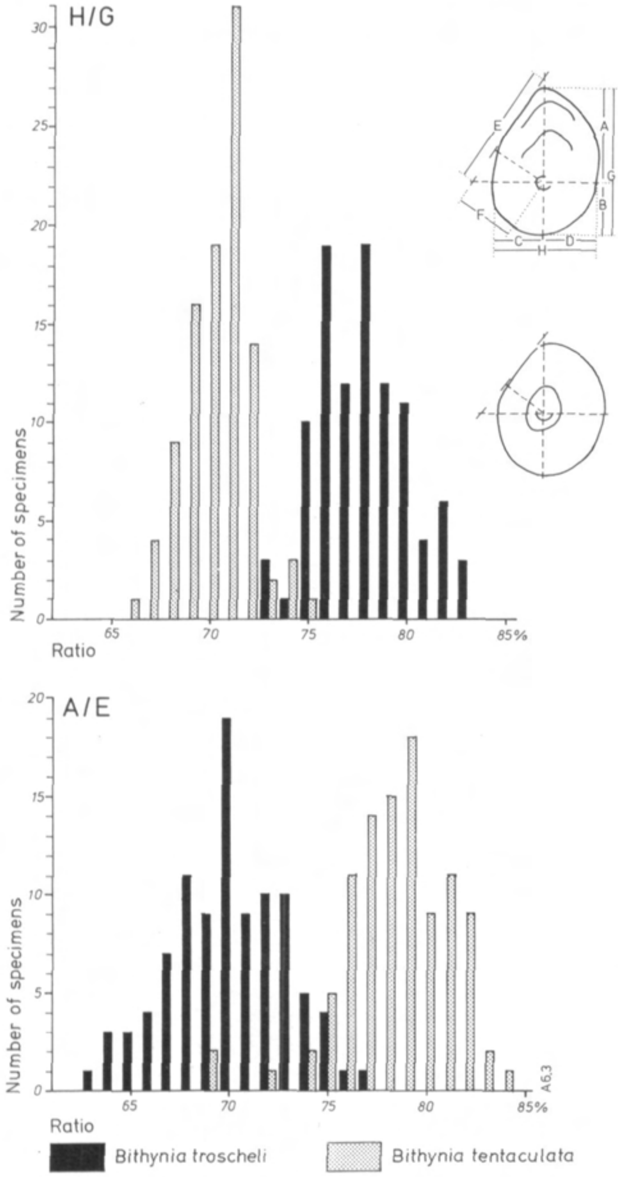


Fig. 2. Results of analysis of measurements in 200 *Bithynia* operculums

Dotted columns: apically pointed specimens (upper operculumn drawing - *Bithynia tentaculata*).

Black columns: apically blunt specimens (lower operculum drawing - *Bithynia troscheli*)

Bimodality of especially the width/height ratio is pronounced, indicating marked difference between the operculums of the two species.

Lymnaeidae

Most of the material is broken, and identification of species had to be based on juveniles and apical and other fragments. Mainly on the basis of apertural fragments, the *Radix* apices are considered to belong to *R. ovata*. *R. peregra,* however, cannot be excluded with certainty, unlike *R. auricularia*. Some adult specimens clearly belong to *Lymnaea corvus,* but no attempt has been made to distinguish juveniles of this species from *Stagnicola palustris*. It is not clear whether other *Stagnicola* species are present as well. *S. palustris* is evidently more common than *Lymnaea corvus,* and juveniles are considered to belong mainly to the former. Juveniles of *Galba truncatula* are clearly distinct from *Stagnicola* and *Lymnaea*. The shell surface of juveniles of both of the latter genera is glossier and smoother than in *Galba,* which has very pronounced riblets. The whorls of *Galba* are generally more tumid and the protoconch is smaller. Besides these characters there are colour differences. Although all of the shell material has lost most of its original colour, some species show remnants of it. *Galba* specimens sometimes show traces of a yellowish colour, and *Stagnicola* occasionally has a reddish-brown apex.

Galba truncatula occurs in periodically desiccated habitats and is frequently found in wet places above the water level. There, it is a member of the *Succinea elegans - Zonitoides nitidus* land snail community.

Planorbidae

Some relevant data pertaining to the vertical distribution are as follows: *Planorbis planorbis*: greatest water-depth 1 m (Gloër et al., 1978); *Bathyomphalus contortus:* greatest water-depth 0.5 m; *Gyraulus crista*: greatest water-depth 3 m, optimal depth 1.5 m; *Hippeutis complanata*: greatest water-depth 3 m, optimal depth 2 m (Ökland, 1964); *Gyraulus laevis*: observed water-depth between 0.20-1.50 m (Kuijper, 1971).

The most remarkable planorbid species are *Anisus vorticulus* and *Gyraulus laevis*. These are rare species both in the recent Dutch fauna and in the fossil state, in which they have only been found in interglacial beds. *Anisus vorticulus* now has a European, slightly continental distribution. In the Dutch Quaternary it is already present in late Tiglian deposits. According to Ložek (1964b), the species occurs mainly in limnic chalk deposits (Seekreide).

Data in the literature suggest that *Gyraulus laevis* is a pioneer species. Kuijper (1971) found a preference for stagnant electrolyterich (especially nitrates) fresh water, and observed that presence at a certain locality is restricted in time: after a year or two the species disappears. The observation that this species is characteristic for an unstable habitat, often occurring at the beginning of a limnic succession, is confirmed by the fossil record (e.g. Favre, 1927; West & Sparks, 1960; Sparks & West, 1968). In transitional phases

Gyraulus laevis can occur in large numbers and be accompanied by *Gyraulus crista, Radix peregra, Valvata piscinalis* (*alpestris*), and *Sphaerium corneum.* In the opinion of Sparks & West (1968), this type of freshwater fauna is of great significance: 'Most certainly this is a fauna of a definite environment at a certain stage in an interglacial - a facies fauna comparable with the *Vertigo parcedentata - Columella columella* faunas characteristic of löss conditions in late-glacial periods'.

Gyraulus laevis can easily be confused with *Gyraulus rossmaessleri,* a cold-tolerant species. Although the general shape of both species is very much the same, *G. rossmaessleri* has a considerable larger first whorl than *G. laevis.* It seems possible that reports of the latter species, where it occurs together with cold-tolerant species such as *Succinea schumacheri, Pisidium obtusale lapponicum,* and *Pisidium stewarti,* refer in reality to *Gyraulus rossmaessleri* (e.g. the site at Upton Warren; Coope et al., 1961).

Physa fontinalis

Only fragments of this species were found in Belvédère. A few apices clearly show the specific characters, but the bulk of the material consists only of columellas with part of the aperture, on which the counts were based. *Physa* is extremely rare in Dutch Quaternary deposits, possibly because of the fragility of its shell.

For the living species, Ökland (1964) indicated a depth optimum at 1.5 m and a maximum water-depth at 3 m.

Corbicula fluminalis

Adult specimens of this bivalve have been found in Belvédère locally and very abundantly in faunas poor in species. Juveniles occur regularly in low numbers in faunas rich in species. This pattern of occurrence is almost certainly ecologically determined. The conservation is excellent: remnants of the original pink colour are often present on the inner side of the shells.

Today, *Corbicula fluminalis* has a distribution extending from the Caspian region and the Near East into Asia, and related species occur in Northern Africa in the Nile basin. Recently, Mouthon (1981) reported the species living in the rivers Tagus (Portugal) and Dordogne (France). These occurrences can be considered to represent the first arrivals of this species during the Holocene in Western Europe, although human influence cannot be excluded.

In the Tagus the species lives on sandy and muddy-sandy substrates. The salt content ranges between zero and 30‰; a maximum water temperature of 20°C was measured in places with a low salt content. In the Dordogne the species lives in fresh water on gravel, sand, and mud in a fluviatile regime. Numerous juveniles were found in muddy substrate, accompanied by i.a. *Pisidium moitessierianum* and *P. supinum.* Maximum water temperature: 21°C. Although Mouthon (l.c.) did not mention minimum temperatures, the river sectors in which the species lives never freeze (Mouthon, pers. comm., 1985).

The classic interpretation considering *Corbicula* a characteristic 'interglacial' species, has been rejected by Ložek (1978). *Corbicula* should be a marker species for summer-warm, arid, marginal phases of glacial stages with a distinct continental climate. Recently, Steinmüller (1981) even concluded that the presence of *Corbicula* does not allow unambiguous palaeoclimatic deductions. However, these opinions are not in accordance with the West-European fossil record. The presence of this species is clearly related to warm-temperate stages, although there are indications for a certain continentality.

In The Netherlands, *Corbicula fluminalis* is present in most of the shell-bearing warm-temperate Quaternary stages, except the Holsteinian and the Holocene.

Carychiinae - Plate 1; Figs. 1-3

Two clearly separate species are present, the rarer of which can be assigned with certainty to *Carychium tridentatum.* The more common species raised some taxonimical problems. The habitus of the shell closely approaches that of *Carychium minimum.* However, the columellar apparatus has no resemblance to this species, but slightly resembles *Carychium tridentatum.* Divergence from the latter species, apart from the shape of the shell, concerns the shape of the columellar fold. The same set of characters is found in Polish *Carychium* populations (Berger, 1963). Berger distinguished three types and considered them to be typical *Carychium minimum* (here provisionally called species 1), *Carychium tridentatum tridentatum* (species 2), and *Carychium tridentatum elongatum* (species 3). Species 1 belongs with certainty to the typical *Carychium minimum*: the general shape of shell and columellar apparatus as well as the habitat preference point unmistakably to this species. It has not been found at Belvédère. Species 3 is unquestionably conspecific with *Carychium tridentatum.* Its shape is slightly more elongated than usual, but remains within the normal intraspecific variation. In Belvédère it is the less common of the two *Carychium* species. Species 2 has a very close resemblance to the problematic species of Belvédère. The shape of the shell and the columellar fold are, as in Belvédère, very unlike those of *Carychium tridentatum.* Therefore, this species cannot be conspecific with one the two common European species. Species 2 is more probably a third species, in all likelihood conspecific with *Carychium mariae,* a species hitherto known only for northern Italy and southern Tyrol. The shape of the shell and the development of the columellar and parietal folds strongly point to this species (Strauch, 1977; Meijer, in prep.).

It is interesting to note that Berger observed only two species combinations occurring in one locality: species 1 and 2 in the lowlands and species 2 and 3 in the highlands (Carpathians), the upper boundary of the latter combination lying at an altitude between 300-500 m above see-level. The latter combination occurs in Belvédère. In the recent fauna Berger mentions this combination from Austria too, and it was also encountered in northern Italy (see below).

Concerning the habitat, Berger mentions the following observations (slightly modified):

Species 1: In both forests (then mostly accompanied by sp. 2) and open areas, but particularly in damp meadows.

Species 2: Only in damp or swampy mixed forests, mainly those with an admixture of *Alnus* and *Fraxinus*.

In woodland, these two species inhabit very similar habitats.

Species 3: In habitats similar to those preferred by species 2. Usually under stones in mountain brooks and in *Pinus* and *Fagus* forests.

From these observations it is clear that the combination of species 2 and 3 (most probably *Carychium mariae* and *Carychium tridentatum*) points to moist deciduous forests in a more continental climate than that of Belvédère today.

Berger did not mention the composition of the fauna in which the Polish species occur. As already mentioned, *Carychium mariae* lives in northern Italy, for which Kofler and Kolman (1974) gave faunal lists for 27 localities situated between 200 and 2400 m altitude. Most of the observations were made at 1100-1600 m. These authors listed a total of 91 species occurring in different places together with *Carychium mariae*; most of these, however, were found only once or a few times. It is interesting that *Vertigo substriata* was encountered in rather many faunas. Table 2 shows the presence of species occurring in more than 25% of the faunas. The same is done for faunas with *Carychium mariae* and *Vertigo substriata* in common. Application of the ecological grouping system to these Italian faunas gives following results (A: faunas with *Carychium mariae,* B: faunas with *Carychium mariae* and *Vertigo substriata* in common) in percentage:

	A	B
woodland	33.3	39.1
open-ground	20.0	13.0
mesophiles	20.0	17.4
hygrophiles	26.7	26.1
fresh water	–	4.3

These percentages point to moist semi-forested conditions and seem to confirm the habitat preference of the supposedly conspecific Polish *Carychium* sp. 2. The Belvédère form is considered provisionally to be *Carychium* cf. *mariae.* Taxonomic and other problems concerning European Carychiinae will be dealt with in a separate paper (Meijer, in prep.).

The only known fossil occurrence of *Carychium mariae* is in Upper Pliocene deposits at Mainz-Weissenau, FGR (Geissert, 1983).

Cochlicopa species - Plate 1, Figs. 7-9

Most of the material consists of fragments; few complete specimens of this uncharacteristic genus are available. From our material it is clear that three species are present: *Cochlicopa lubrica, C. lubricella,* and *C. nitens.* Besides the shape of the shell, identifications are based on the width of the last whorl: *C. lubricella*: 1.91-2.39 mm, *C. lubrica*: 2.35-2.70 mm, and *C. nitens*: 2.83-3.13 mm.

In contrast to the two other species, *Cochlicopa nitens* has never been found as a fossil in The Netherlands.

Cochlicopa nitens is, like *Vertigo moulinsiana*, a typical inhabitant of calcareous swamps. According to Ložek (1958), its occurrence in communities of lateglacial character constitutes evidence that this species can endure a cool climate and appeared much earlier in Holocene times than the ecologically related *Vertigo moulinsiana.* According to Kerney, Cameron and Jungbluth (l.c.), the species normally occurs in calcareous swamps but can also live in very moist forests on calcareous soil. Nilsson (1956) mentions it from *Carex, Phragmites* and *Scirpus* vegetations.

The recent distribution shows a certain continental pattern; the mid-European isolated populations are thought to be the westernmost occurrences of a more eastern-continental Eurasiatic distributional area (Nilsson, l.c.).

Vertigo species

Six species of this genus have been found; all of them are more or less confined to temperate phases. Two are of more special interest: *Vertigo substriata* and *V. moulinsiana.*

Vertigo substriata

At present, this species is rather scarce in The Netherlands. The species is confined to humid, shady habitats, often in deciduous forests, and is found in e.g. various types of *Alnetum, Crataegus/Betula* shrubs, *Fagus* forests and forests with *Corylus, Populus,* and *Fraxinus.* In Denmark the species has usually been found together with *Spermodea lamellata* in *Fagus* forests (Sunier, 1926).

Table 3 shows the associated species present in 39 Dutch recent faunas. The data are based on a review of the Dutch literature and unpublished observations of Kuijper (pers. comm., 1971). Only species with a presence of more than 25% have been taken into account. Interesting species found in lower percentages are *Zonitoides excavatus* (20.5%) and *Spermodea lamellata* (7.7%). It is striking that only two species (*Columella aspera* and *Oxychilus alliarius*) are absent in Belvédère. Ecological grouping of the data in Table 3 gave the following result: woodland species: 33,3%; open-ground species: 0%; mesophiles: 40%; and hygrophiles: 26.7%.

The following climatic conditions are preferred: high air humidity but avoidance of direct contact with water; precipitation in all seasons, between 500-1000 mm/year (and more); mean July temperatures: ranging between 14° and 22°C.

According to Lozek (1964b), the species occurs in warm-temperate phases and humid oceanic parts of cold phases.

Vertigo substriata has been found in The Netherlands sporadically as a fossil in the Holocene.

Vertigo moulinsiana

The recent distribution has an atlantic-meridional pattern. This pattern is clearly expressed in the fossil record: the species only occurred in times with a humid warm-temperate climate.

There is an extensive literature on the faunistics and ecology of the species, its peculiar habitat being relatively well known. *Vertigo moulinsiana* occurs in calcareous swamps, in the vicinity of *Alnus* woods. It usually lives on tall *Carex* and *Glyceria* species growing in less shallow water, and was found in the *Juncetum-acutiflori, Magnocaricion,* and the *Valerianeto-Filipenduletum* plant-communities (Butot & Neuteboom, 1958). The only associated snail species on the vegetation are *Succinea putris, S. elegans,* and *Columella edentula;* the soil surface-dwelling species are *Carychium minimum, Cochlicopa lubrica, Vertigo antivertigo, Deroceras laeve, Vitrea crystallina, V. contracta, Aegopinella pura, A. nitidula, Zonitoides nitidus, Eucobresia diaphana, Vitrina pellucida,* and *Euconulus fulvus.* Ecological grouping of these species results in: woodland: 28,6%; open-ground: 0%; mesophiles: 7.1%; and hydrophiles: 50%.

The species prefers the following climatic conditions: high airhumidity; a yearly rainfall of at least 600 mm; a mean annual temperature of 10°C; mean July temperatures of at least 15°C, recent distribution mainly south of the 17°C isotherm. Mean January temperatures above −5°C, the largest part of its area lying south of the 0°C isotherm (Johansen, 1904; Kerney, Cameron and Jungbluth, 1983). The species endures a temperature amplitude ranging from −10°C to +30°C (Butot & Neuteboom, 1958).

In Dutch Quaternary sediments the species has been recorded from the Bavel Interglacial and several Holocene deposits.

Vallonia enniensis

This species lives by preference on humid to wet meadows, but also in bushes where the humidity is high enough. It is highly characteristic for calcareous swamps and is reported to flourish in *Phragmitetum, Caricetum,* various types of *Alnetum,* etc. (Plate, 1950). In Hungary, Bába (1969) observed the species living in Ash-Alder woods. These woods are completely inundated except during August and the first half of September. For a short time the species can withstand dry conditions. Occurrence between *Sphagnum* in a peat bog has also been observed (Matzke 1969; Plate, l.c.).

Table 3 gives the recent associated species with a presence of more than 25% in ten German and Hungarian faunas. Ecological grouping of the species gives the following result: woodland species (bushes): 11.1%; open-ground species: 22.2%; mesophiles: 33.3%; and hygrophiles: 22.2%.

According to Plate (l.c.), the optimum of the species is in humid and warm biotopes. This is expressed in the recent distribution too: the distributional area is more or less closed south of the 20°C July isotherm.

In the recent fauna of The Netherlands the species

Table 2. *Carychium mariae*: associated species with a presence greater than 25% in 27 recent North-Italian faunas (based on Kofler and Kollman, 1974.)

	A	B
Carychium mariae	100.0	100.0
Euconulus fulvus	66.7	91.7
Cochlicopa lubrica	55.6	58.3
Nesovitrea hammonis	44.4	58.3
Vertigo substriata	44.4	100.0
Columella edentula, agg.	40.7	58.3
Discus ruderatus	37.0	33.3
Macrogastra lineolata	33.3	+
Succinea oblonga	29.6	25.0
Vertigo antivertigo	29.6	25.0
Vitrea subrimata	29.6	25.0
Eucobresia diaphana	25.9	41.7
Pupilla muscorum	25.9	33.3
Macrogastra plicatula	25.9	33.3
Vertigo pygmaea	25.9	25.0
Ciliella ciliata	25.9	+
Radix peregra	+	25.0
Vertigo alpestris	+	25.0
Causa holosericum	+	25.0
Isognomostoma isognomostoma	+	25.0
Vallonia pulchella	+	25.0
Semilimax kotulae	+	25.0
Carychium tridentatum	+	25.0
Succinea elegans	+	25.0
Punctum pygmaeum	+	25.0
Fusulus varians	+	25.0

+ presence lower than 25%

Column A: presence (%) in 27 faunas with *Carychium mariae*

Column B: the same in 12 faunas with *Carychium mariae* and *Vertigo substriata* in common

Table 3. Recent associated faunas of five land-snail species.

	A	B	C	D	E
Carychium minimum, agg.	+	60.0	+	x	+
Carychium tridentatum	+	–	+	–	–
Succinea oblonga	30.8	+	40.0	x	+
Succinea putris	+	60.0	+	–	+
Cochlicopa lubrica, agg.	79.5	70.0	85.0	x	61.1
Columella edentula, agg.	38.5	–	65.0	x	61.1
Columella edentula, seg.	17.9	–	–	–	–
Columella aspera	17.9	–	10.0	–	–
Vertigo pusilla	35.9	–	30.0	x	27.8
Vertigo substriata	100.0	+	45.0	x	50.0
Vallonia costata	+	60.0	25.0	–	+
Vallonia enniensis	–	100.0	–	–	–
Vallonia pulchella	+	60.0	+	–	+
Acanthinula aculeata	25.6	–	100.0	x	55.6
Spermodea lamellata	+	–	+	100.0	+
Punctum pygmaeum	79.5	–	75.0	x	61.1
Discus rotundatus	30.8	–	65.0	x	50.0
Vitrina pellucida	59.0	+	75.0	x	44.0
Vitrea crystallina, agg.	33.3	+	55.0	x	38.9
Vitrea contracta	2.6	20.0	15.0	x	5.6
Nesovitrea hammonis	76.9	50.0	70.0	x	77.8
Aegopinella nitidula	+	–	35.0	x	+
Aegopinella pura	+	+	50.0	x	38.9
Oxychilus alliarius	30.9	–	40.0	x	55.6
Zonitoides excavatus	+	–	45.0	x	100.0
Zonitoides nitidus	+	80.0	+	x	+
Euconulus fulvus	84,6	50.0	55.0	x	72.2
Clausilia bidentata	+	–	25.0	–	–
Bradybaena fruticum	–	30.0	–	–	–
Trichia hispida	+	–	40.0	–	+

Column A: 18 Dutch faunas with *Vertigo substriata*

Column B: 10 European faunas with *Vallonia enniensis*

Column C: 20 Dutch faunas with *Acanthinula aculeata*

Column D: associated species of *Spermodea lamellata* in three places in the Mantinger Bos (province of Drente, The Netherlands)

Column E: 18 Dutch faunas with *Zonitoides excavatus*

Values are percentages representing presence in the faunas with one of the five species in common; + = present in less than 25% of the faunas, x = present; – = absent.

is absent. It has been found, however, in Holocene calcareous tufas near Kanne in the Jeker valley. There the species was present from Preboreal to at least Atlantic times. In the Pleistocene it is only known from the Bavel Interglacial.

Acanthinula aculeata

A typical woodland species, living in leaf litter, between dead leaves, affixed to the underside of logs, etc. According to Evans (1972), it can also be found in quite open grassy glades, though never far from sheltered habitats. Ant (1963) found the species to be distinctly shadow loving and dependent on a high air humidity. In general, *Acanthinula* lives in humid forests, avoiding warm-dry treeless areas (Ložek, 1964b).

For 20 recent Dutch faunas, the associated species with a presence of more than 25% are shown in Table 3. It should be mentioned that *Spermodea lamellata* occurs in 15% of these faunas.

Ecological grouping of these data gives the following result: woodland species: 45%; open-ground species: 5%, mesophiles: 35% and hygrophiles: 20%.

Acanthinula aculeata occurs in warm-temperate phases. In Dutch Quaternary deposits it is very scarce and only a few specimens have been found in Holocene beds.

Spermodea lamellata

A characteristic species for old woodland, especially the *Fago-Quercetum*. It lives in thick layers of leaf litter and is often mentioned as occurring under a vegetation of Holly (*Ilex aquifolium*). In the only place where the species occurred in The Netherlands, the Mantinger Bos (province of Drente), it was found between wet leaves and litter of Holly, Oak, and Beech (Van Regteren Altena, 1931; Van der Tooren, 1963).

In the recent fauna *Spermodea lamellata* is often accompanied by *Vertigo substriata* and *Zonitoides excavatus*. Table 3 gives the associated species at three sampling stations in the Mantinger Bos. Ecological grouping of these species gives the following result: woodland species: 50%; open-ground species: 0%; mesophiles: 25%; and hygrophiles: 35%.

At present the species has a distinctly atlantic distribution and is not, as was formerly thought, restricted to northwestern Europe, but occurs in Portugal too (Gittenberger, 1977). The area in which the Mantinger Bos is situated belongs to the coolest part of The Netherlands (mean July temperature: circa 16.5°C, mean January temperature: circa 1°C), but also has the highest precipitation (mean annual precipitation: more than 800 mm, net precipitation: more than 300 mm). Johansen (1904) mentions a lowest mean July temperature of circa 13°C.

So far, *Spermodea lamellata* has not been found in Quaternary deposits in The Netherlands.

Limacidae and Milacidae

The only remains of slugs are the degenerated, internal, flat, oval shells. Unlike the spiral external shells of most non-marine snails, they are composed of calcite, which explains why they are often found together with bithyniid operculums.

Shells of slugs have few characteristic features. Normally, only the main taxa can be distinguished and this has important consequences for the ecological grouping. This group is treated by palaeomalacologists in different ways: either all slugs are considered to constitute a single 'ecological' group (e.g. Puisségur, 1976) or the main taxa are assigned to the various ecological groups: Milacidae and large Limacidae to the woodland group, small Limacidae to the mesophile group (Lozek, 1964b). The latter approach is followed here in an attempt to arrive if possible at identification on the species level. This is hampered by the fact that illustrations of the shells of recent slugs are usually not given in the literature. Reuse's (1983) conclusion that identification on species level is hardly possible, is not accepted by the present author and should be considered premature.

The Arionidae, slugs not related to Limacidae and Milacidae, were formerly considered to be responsible for the calcitic grains now commonly recognized as remains of *Lumbricus*. These calcitic grains are often very numerous and outnumber the molluscan remains present in a sample. Nevertheless, several authors still consider the calcitic grains to be of Arionid origin and to constitute a single ecological group together with the Limacidae (e.g. Gremmen, Hannss & Puisségur, 1984). The result is a considerable distortion of the ecological picture of a molluscan fauna.

In Belvédère all three main taxa of slugs are present. Some comments are required here.

Milacidae - Plate 2, Fig. 4

Only one well-defined species is present in the upper part of all sections. The same type of Milacidae was found in several deposits of Lower and Middle Quaternary age (unpublished observations of the present author). At these localities it is found together with, i.a. *Vertigo pusilla, Discus rotundatus, Vitrea crystallina, Aegopinella nitidula, Clausilia bidentata, Cl. cruciata, Cl. pumila, Macrogastra lineolata, Cochlodina laminata, Perforatella bidentata, Helicigona lapicida, Arianta arbustorum,* and *Cepaea nemoralis.* Since these species all belong to communities living in deciduous forests, the Milacidae species is considered to be a member of the same group.

It is not yet clear which Milacidae species is concerned here.

Limacidae - Plate 2, Figs. 5-9

Only one specimen belonging to a large species has been found. This specimen can be assigned to a *Limax* or *Lehmannia* species. The remaining material belongs to small species, most probably *Deroceras* spp. Two types could be distinguished. One of them is very scarce and is found in the lower parts of the sections. The other, more common type, is almost certainly of polyspecific origin and occurs in most of the samples. The scarce type has been tentatively identified as *Deroceras agreste,* mainly on the basis of the location of the nucleus, i.e., in the middle of the posterior side. The species has a northern, eastern, and mountainous distribution and inhabits wet meadows (Kerney, Cameron and Jungbluth, 1983). So far, in The Netherlands it has been found in what is called Brabantse Leem, a Weichselian loess deposited under wet conditions. The species occurs there together with i.a. *Succinea oblonga elongata, Succinea elegans schumacheri, Columella columella, Vertigo genesi, Pupilla alpicola, Gyraulus rossmaessleri, G. acronicus,* and *Aplexa hypnorum.* This community points to cold, open, and wet conditions. The present author has found *Deroceras agreste* in a calcareous tufa of Allerød age near Kirf (Rheinland-Pfalz, FRG), where it is accompanied by i.a. *Vertigo genesi, V. substriata, Vallonia costata, Clausilia bidentata, Eucobresia diaphana,* and *Arianta arbustorum,* a fauna living in cool, semi-forested, and wet conditions. In sum, *Deroceras agreste* can be considered characteristic for cool, wet, and open to semi-forested conditions.

Zonitoides sepultus - Plate 2, Fig. 2

This is the only extinct species present. For conchological differences with respect to the more common species *Zonitoides nitidus* (Plate 2, Fig. 3), the reader is referred to Ložek (1964a). The white colour of *Zonitoides sepultus* from Belvédère is in contrast with the characteristic brown colour of *Zonitoides nitidus,* a striking feature also mentioned by Dehm (1951). Besides general shell character and resemblance in habitat preference, this type of colour conservation may point to a relationship with the northwest European *Zonitoides excavatus.*

Since its description in 1964, the species has been found in about 17 Central-European sites. The stratigraphic record of the faunas ranges from late Tiglian up to and including 'Treenian'. Here, Treenian must be considered as a warm period which occurred between the Holsteinian and the Eemian. The age of the majority of the faunas is, however, thought to be Cromerian (in the wider sense) on the basis of the molluscan and vertebrate evidence (Dehm, 1969; Ložek, 1964a, b). *Zonitoides sepultus* has not yet been found in Dutch Quaternary deposits. The Belvédère site is the westernmost occurrence now known. Therefore, it cannot be excluded that during deposition of Unit 4 of the Belvédère sequence the climate was more continental than it is at present.

All available European data show clearly that *Zonitoides sepultus* lived in a moist deciduous forest habitat on calcareous soils; in this respect it is important to note that 50% of the records are from travertines and calcareous tufas containing deciduous forest faunas. On these grounds, the species is assigned to the woodland species group.

In addition, it is interesting to look at the perhaps related *Zonitoides excavatus.* In the recent fauna this species is frequently found together with *Vertigo substriata* and *Spermodea lamellata* (Venmans, 1950). Table 3 shows the associated species of *Zonitoides excavatus* occurring in 18 Dutch recent faunas. Only species with a presence of more than 25% have been taken into account. *Spermodea lamellata* was present in less than 25% of the faunas. Ecological grouping of the species gives: woodland species: 50% open-ground species: 0%, mesophiles: 37.5%, and hygrophiles: 12.5%. These figures confirm the woodland character of *Zonitoides excavatus. Zonitoides excavatus* and *Sphermodea lamellata* are considered characteristic for the *Fago-Quercetum* (*Quercus-Ilex* forest) on slightly acid soils (Visser, 1971). Where the soil is less acid the forest has a wider composition including *Corylus,* and here *Zonitoides excavatus* is absent. In this type of forest *Spermodea lamellata* and *Vertigo substriata* occur.

It does not seem unlikely that *Z. excavatus* and *Z. sepultus* formed a species pair, the former living in the *Fago-Quercetum* under oligotrophic conditions, the latter in the *Fago-Quercetum* mixed with *Corylus* under slightly more eutrophic conditions. Modern examples of such pairs are provided by *Columella edentula-Columella aspera* and *Euconulus fulvus fulvus-Euconulus fulvus alderi.*

Helicopsis striata - Plate 2, Fig. 1

Identification is mainly based on the size of the protoconch by which this species is, according to Sparks (1953), most significantly distinct from *Trochoidea geyeri.* According to Ložek (1964b), the species prefers sunny-dry grassy slopes and lives on loose substrates. It avoids humid places and can be considered a typical steppic element. Ant (1963) classified it as a continental species, demanding warm summers. At present the species lives in Central Europe, especially in Germany and Hungary. It does not occur in the recent fauna of The Netherlands, and the occurrence in Belvédère is the first known from the Dutch Quaternary.

In Mid-European loess deposits the species is a member of what is called the Striata fauna, which occurred in warm-dry phases (interstadials) of glacial stages (Remy, 1968). These faunas differ widely in character and have considerably fewer species than the Belvédère fauna.

Traces of predation on gastropod shells - Plate 1, Figs. 4-6

Some shells of land gastropods show small holes among which different types can be distinguished. There are two main groups: one characterized by an almost circular hole looking as though it had been cut out, which is left after removal of the apex, and the other by an oval hole, in the wall of the shell, bordered by a zone in which the upper shell layer has been removed by lengthwise rasping. Often grooves can be seen in a direct line with an oval hole, but grooves without a hole are also observed.

Both types of hole occur in various sizes, but no relationship was found between the size of the hole and the size of the attacked shells. In all probability these holes are left by snail eating organisms and can be interpreted as traces of predation. The organism which left these traces of predation is not known but insects may be responsible. The apex-cutting predator seems to have lived under slightly wetter conditions than its wall-rasping colleague. This is shown by the snail species attacked. Gastropods with missing apices include *Carychium* cf *mariae, Cochlicopa* sp., *Vertigo antivertigo, Vallonia costata, V. enniensis, V. pulchella, Vitrina pellucida, Euconulus fulvus,* and *Trichia hispida.* Wall-rasped gastropods include *Carychium* cf *mariae, Cochlicopa* sp., *Vertigo antivertigo, V. moulinsiana, V. pygmaea, Pupilla muscorum, Vallonia costata, V. enniensis, V. pulchella, Euconulus fulvus, Punctum pygmaeum, Clausilia parvula,* and *Trichia hispida.*

Most of the specimens with traces of predation are found in section Mol. 3. The wall-rasped shells from this section were counted, and the results are represented in diagram form. The curve is included in the molluscan diagram. (of this section). The shape of the diagram resembles that of the diagrams of the hygrophiles and of fresh-water species living in marshy habitats (diagrams of individuals).

Lumbricus terrestris - Common Earthworm

As already mentioned, at one time calcareous remains of the Earthworm were often considered to be rudimentary shell structures of slugs belonging to the Arionidae. The remains look like small ovoidal or subspherical granules and usually have a maximum diameter of about 0.5 to 1.5 mm. They have a radial crystalline structure, and sometimes show crystal facets on their outer surface. Analyses with an X-ray powder diffractometer proved them to be composed of pure calcite of a non-magnesian type (Kerney, 1971). Similar observations have been made by Bräm (1956) and Leiber and Maus (1969). The latter authors investigated the chemical composition as well and found only calcium carbonate without detectable organic material or trace elements.

Recent granules of *Lumbricus* were described by Bräm (l.c.), who showed them to be identical with fossil calcitic granules. He dissected specimens of several species belonging to different genera, and found the granules only in *Lumbricus terrestris.* Dissolution of 80 specimens of this species in caustic soda produced 46 granules larger than 1 mm and 200 smaller ones. The present author obtained similar results with dissolution of several hundred specimens of the same species.

The granules are produced in calciferous glands. Having reached a certain size (not always the same size), they are secreted into the oesophagus, pass through the intestine, and are excreted with the faeces. The function of the calciferous glands is not yet fully understood, although Piearce (1972) found indications of a relationship with the diet. Secretion has also been observed in the calciferous glands of some other species, but the nature of the substance is not indicated by the literature (Piearce, l.c.). It therefore seems that pure crystalline, calcitic, granules are produced only by *Lumbricus terrestris.*

When the ground-water table is low, *Lumbricus terrestris* is able to burrow down to 3 metres below the surface. The inner wall of the burrows is reported to be plastered with a 2 mm-thick layer of faeces. The bulk of the faeces, however, is excreted on the surface and accumulates around the opening of the burrow (Van Rhee, 1970, 1977). The present author has found many calcitic granules in such faeces accumulations. This evidence suggests that the highest concentration of calcitic granules occurs on the surface, that is to say, at the same level where remains of molluscs accumulate. Hence, it is hardly surprising that there is a relationship between fluctuations in the numbers of calcitic granules and molluscs in fossil assemblages, a phenomenon which has been frequently observed and also used as evidence of the Arionid affinity of the granules (Bräm, l.c.; Kerney, l.c.).

Lumbricus terrestris prefers humid conditions, and reproduction is reported to be stimulated in moist periods (Van Rhee, 1970). Large fluctuations in temperature are very unfavourable, therefore *Lumbricus* shows a preference for soils covered by a dense vegetation of herbs and grasses, where extremes in temperature are reduced. This means that *Lumbricus* can be found on grassland as well as in forests with a well-developed undergrowth. A high calcium content and a low acidity of the soil are also favourable for worms. Under these conditions, humification of what is called the mull type takes place.

According to Scheffer/Schachtschabel (1976), mull is formed in soils with favourable water and air conditions as well as a relatively high nutrient content, conditions under which litter decomposes rapidly. Mull humification is restricted to types of vegetation that produce easily mineralizing litter rich in nutrients. This means that mull can be found especially under a steppic vegetation and under deciduous forests with a rich undergrowth of herbs and shrubs, but also in most meadows.

Unlike mull, the form of humus called mor develops primarily under pine and deciduous forests with little or no undergrowth on relatively nutrient-poor soils or under cool-humid climatic conditions. *Lumbricus terrestris* avoids soils with mor formation (Scheffer/Schachtschabel, l.c.).

From all this, the following can be concluded:

a. Calcitic granules are produced by earthworms, in all probability only by *Lumbricus terrestris.*
b. The highest concentration of granules occurs at about the same level as mollusc accumulation. Development of both groups in a fossil record can therefore be considered to have been contemporaneous.
c. Unfavourable conditions include dryness, large temperature fluctuations, freezing, and a high acidity and low calcium content of the soil.
d. Favourable habitats are provided by soils covered with dense vegetations composed of grass, herbs, and shrubs, on open-ground as well as in deciduous forests. This means in general that pine forests or deciduous forests with little undergrowth are avoided.
e. Favourable climate is characterized by relatively cool, wet summers and mild winters, in other words a climate of a more or less atlantic type.

Calcitic granules are often found in Dutch Quaternary beds, but only in sediments dating from interstadial and interglacial periods. They occur commonly in river sediments and reach very high numbers in loess deposits. In a Weichselian loess at Nagelbeek (province of Limburg), counts showed 30.000 granules in one litre of sediment. The granules occurred together with a molluscan fauna of 415 individuals. The fauna, in which *Trichia hispida* was dominant, pointed to cool and moist tundralike conditions during an interstadial (unpublished report). The very different magnitude of the *Lumbricus* and mollusc numbers indicates how the ecological picture shown by the molluscan assemblage would be affected if the granules were considered to be of arionid origin and included in the counts.

On the other hand, because *Lumbricus* has often been erroneously identified as Arionidae, much hidden information on earthworms can be extracted from literature on Quaternary non-marine molluscan faunas.

At the Belvédère site, granule numbers do not exceed 2000 specimens per litre of sediment. From the diagrams of Mol. 2 and 3 it appears that best conditions for earthworms prevailed during the period of zone D. Because zone D shows a quite different ecological pattern in the two sections, it seems highly probable that the *Lumbricus* maximum was climatically controlled.

ECOLOGICAL DIAGRAMS OF INDIVIDUALS (see Fig. 3)

In this chapter the development of the faunas which are present at various places in Unit 4 of the Belvédère sequence will be discussed. The ecological conclusions are based for the greater part on the mollusc diagrams which are constructed for the sections and single samples that have been studied. Except for sample Mol. 5 their location is shown in Fig. 1.

Section Mol. 1

The fauna is monotonous, poor in species and rich in individuals; freshwater molluscs are predominant. The poor terrestrial fauna lacks woodland species and is dominated by *Pupilla muscorum, Trichia hispida,* Succineidae, and Limacidae. Among the slugs, *Deroceras agreste,* which prefers open, wet, and cool conditions, is present. The terrestrial fauna as a whole points to an open landscape and very probably a cool climate. The freshwater fauna comprises *Valvata piscinalis* (dominant), *Gyraulus laevis, Radix peregra, Sphaerium corneum,* and *Pisidium* species. This association is a characteristic pioneer fauna occurring in an early, poorly vegetated phase of a limnic developement. The fluviatile *Pisidium* species, which are present in relatively large numbers, may have survived as a relict from the river regime that prevailed in the terrace gravels (Unit 3). Often a *Valvata piscinalis/Gyraulus laevis/Sphaerium corneum* association is found in the transitional phase between cold and temperate stages (e.g. Favre, 1927; Johansen, 1904; Ložek, 1964b; Sparks, 1968).

It does not seem unlikely that such a phase is also represented here: both terrestrial and freshwater faunas suggest this. Since arctic elements are absent, the present author considers the section to represent an early temperate zone.

The other sections, to be discussed below, show larger numbers of species. Aquatic as well as terrestrial molluscs are more demanding. There are more aquatic gastropods living in vegetation than are found in section Mol. 1. Among the terrestrial fauna a certain number of woodland species are present. *Gyraulus laevis* occurs only in the lower parts of sections Mol. 3 and 4, and *Deroceras agreste* is absent. It is clearly indicated that section Mol. 1 pre-dates the other sections.

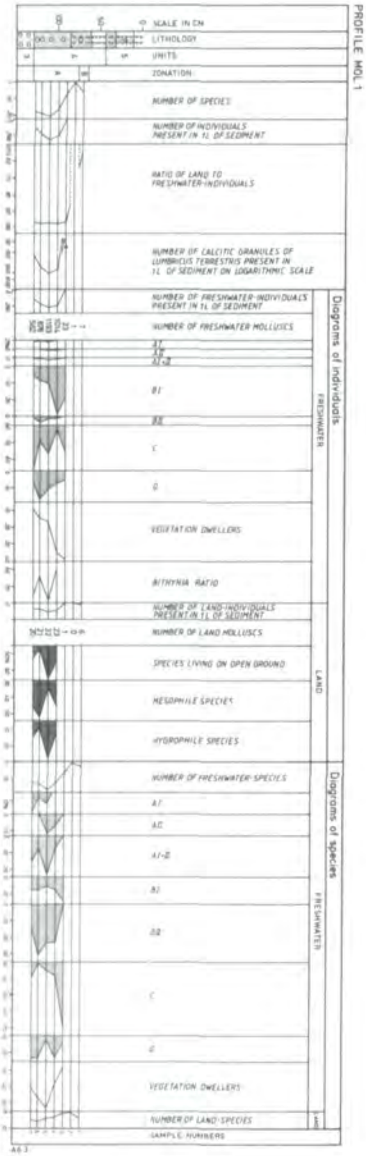
Section Mol. 2

The entire section was deposited in standing water and shows a succession from rather shallow, well-vegetated water to deeper, slightly less vegetated water. The *Bithynia* ratio decreases from 90 to 70%, reflecting the same development. Fluviatile species are present, but only in low numbers. The freshwater fauna is better developed than in section Mol. 1. *Gyraulus laevis* is absent, whereas more demanding species, for instance *Physa fontinalis, Anisus vortex, A. vorticulus,* and *Hippeutis complanata,* are present. In the upper part of the section they are accompanied by *Planorbis carinatus* and *Segmentina nitida.* Most noteworth is the occurrence of juveniles of *Corbicula fluminalis.* This species points to a warm-temperate climate with a continental accent. The occurrence of only juveniles is evidence of a quiet-water regime. The terrestrial fauna points strongly to a well-developed *Magnocaricion,* possibly with scattered *Alnus* bushes. *Vertigo moulinsiana* is significant for this vegetation, but the following species also fit into this habitat very well: *Carychium* cf. *mariae, Succinea elegans/putris, Cochlicopa lubrica, Vertigo antivertigo, Vallonia enniensis, Vitrea crystallina, Aegopinella nitidula, Zonitoides nutidus,* Limacidae, *Vitrina pellucida,* and *Euconulus fulvus.* It is interesting to note that the fluctuations of the values of the hygrophiles and the forest ratio are coupled. This seems to be consistent with the combination of *Magnocaricion* and *Alnus* bushes. The same kind of fluctuation can be found in the ratio of freshwater to land individuals and the fresh-water ecological groups A and C. It seems reasonable to attribute the similarity of these curves to a common cause. In all likelihood, the fluctuations were climatically determined and express changes in humidity. Fluviatile species show hardly any fluctuation, which means that the predominant water-regime remained essentially the same, namely lacustrine.

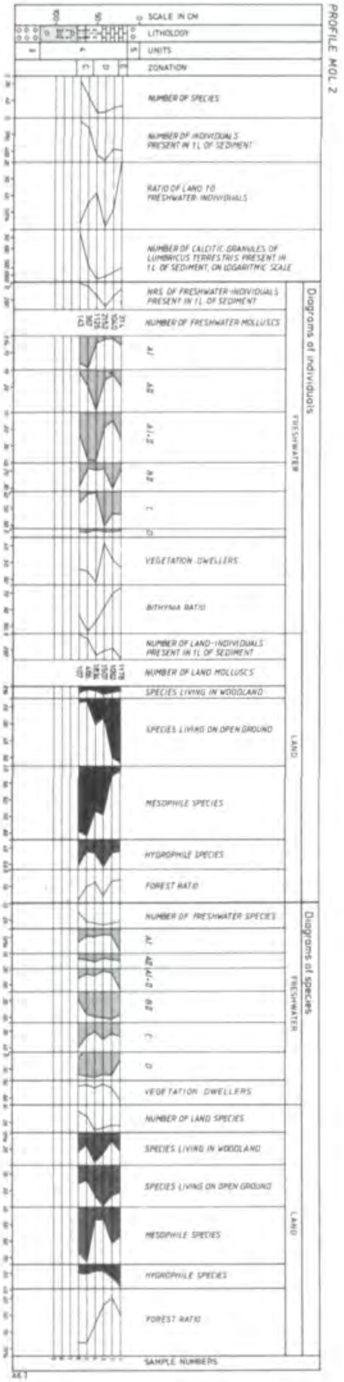
Section Mol. 3

Although the succession here differs completely from that in Mol. 2, the faunas are related. There are rather many species, and a large proportion of them are very demanding. The freshwater fauna in the lowermost part of the section lived in (possibly rather deep) poorly vegetated and gently flowing water. In the area of transition from moving to stagnant water *Gyraulus laevis* is present in relatively large numbers. Since this

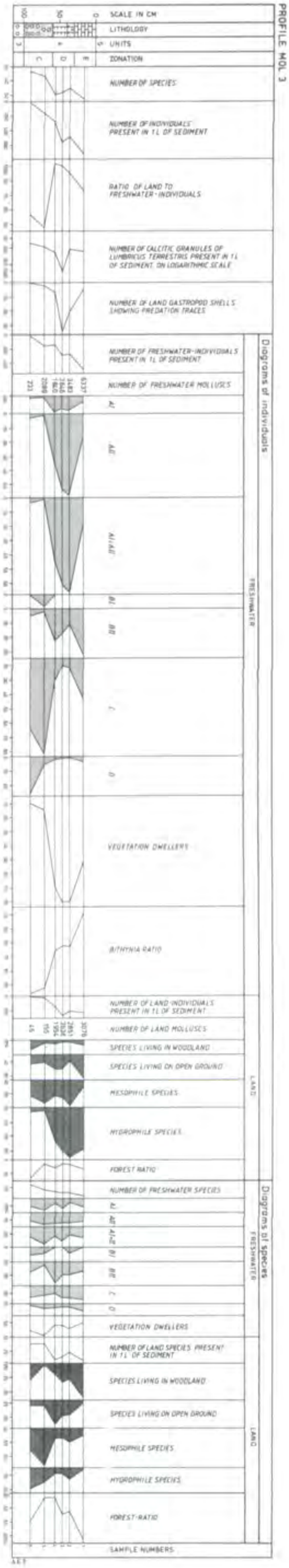
Section Mol. 1

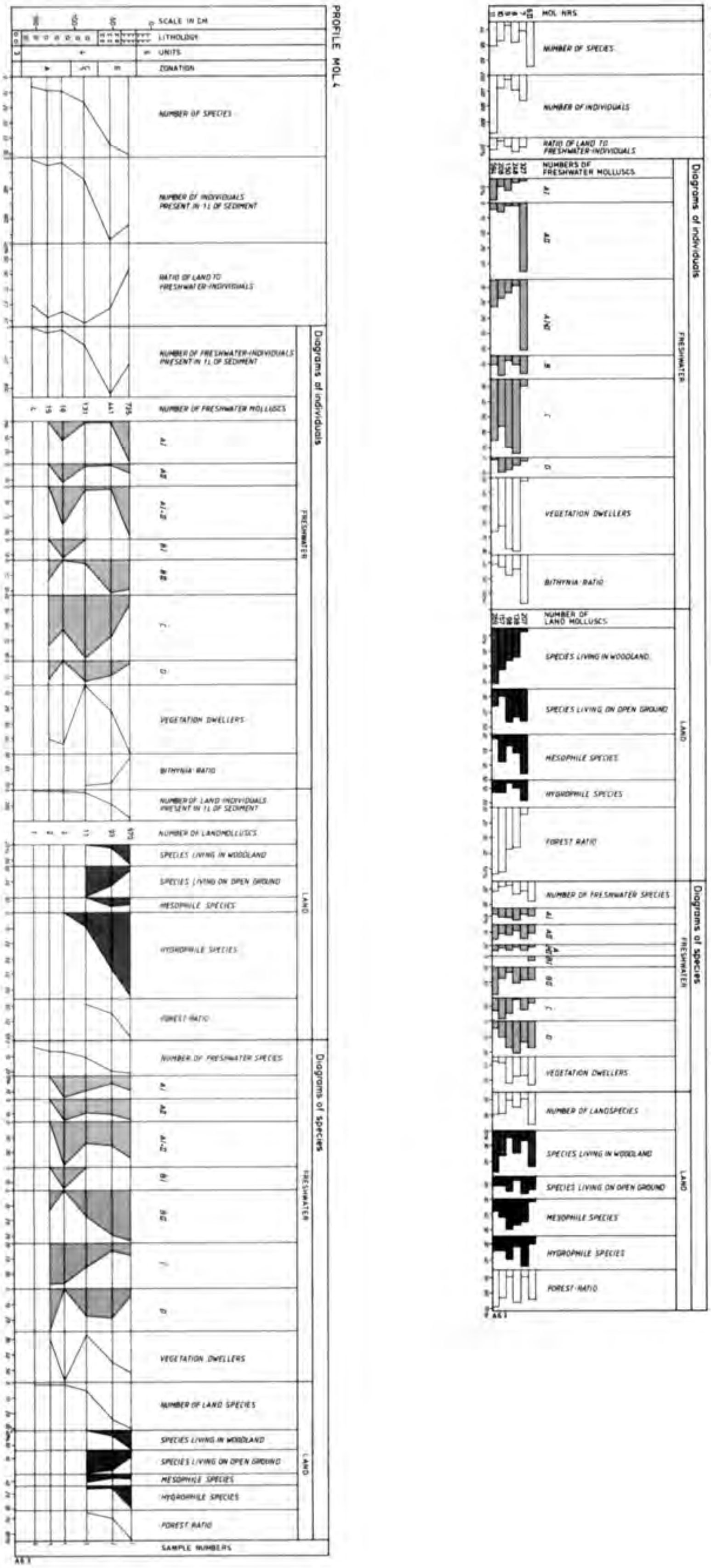


Section Mol. 2



Section Mol. 3





Section Mol. 4

Samples Mol. 6II-11

Fig. 3. Molluscan ecological diagrams for the investigated Unit 4 locations.

species occurs in a complex and more demanding fauna than that found in Mol. 1, it is not very likely that the two sections are synchronous. Nevertheless, there is a parallel: its presence in Mol. 3 again coincides with a poorly vegetated early phase of a limnic succession.

After the *Gyraulus laevis* phase the land molluscs, initially scantily represented, begin to spread. The same holds for the freshwater species living in marshy habitats. The *Bithynia* ratio declines, indicating an increase of quiet-water habitats, the site becoming well vegetated with aquatic plants.

The uppermost part of the section shows a reversal of this trend, except for the *Bithynia* ratio. Marshy habitats decrease and aquatic vegetation becomes less dense. Ecological group B and C both increase, group D only slightly. These trends can be explained by a rise of the water-level. Noteworthy is the switch of the *Bithynia* ratio from more than 50% to less than 50%, indicating that the water became completely stagnant.

In sum, the freshwater succession of Mol. 3 started with poorly vegetated, rather deep, gently flowing water, followed by a phase with decreasing movement of the water, which became shallower and well vegetated. *Gyraulus laevis* occurred during the transition between these phases. The shallow well-vegetated phase is followed by a slightly less vegetated phase with deeper water that had ceased to flow.

The terrestrial fauna in the lower part of the section is characterized by the mesophiles, whereas in the upper part the hygrophiles predominate. The spread of land molluscs in sample 4 is accounted for mainly by the hygrophiles. The expansion of the latter was synchronous with the spread of the marsh-inhabiting freshwater species. Among the hygrophiles, the same species dominate as in section Mol. 2, which shows that the *Magnocaricion* was very important here too. The forest ratio indicates less woodland in the adjacent area than in Mol. 2, which suggests a greater distance between the sample site and drier ground.

In the upper part of this section there are some land molluscs which are absent in section Mol. 2: *Vertigo pusilla, Vitrea contracta, Clausilia bidentata,* and *Macrogastra plicatula.* These species suggest a slightly more developed succession than occurred in the upper part of Mol. 2.

The proportional fluctuations of the various ecological groups are coupled here too, but not in the same way as seen in section Mol. 2. As already mentioned, the development of the hygrophiles closely resembles to that of the marsh-inhabiting freshwater species, being the reverse of that for species living in deeper, more open water. The terrestrial fauna in the strict sense correlates with the freshwater group of stagnant well-vegetated water. These anomalies can be ascribed to a different situation of the sample site in several respects, e.g. the distance to drier ground. Climatic fluctuations severely affect the terrestrial fauna in the strict sense, but when the molluscs are found in aquatic sediments, the expression of the effects diminishes with increasing distance to the habitats from which the thanatocoenosis is derived.

Notwithstanding the anomalies between the terrestrial and freshwater ecological groups occurring in both sections, there are faint similarities between the diagrams of the terrestrial fauna in the strict sense as well as the forest ratios. For this reason the present author considers a synchronic fluctuation of the climate to be reflected in both sections.

Section Mol. 4

Freshwater molluscs predominate throughout the section; land species did not spread until the formation of the upper part of the section. In the middle of the lower part *Gyraulus laevis* occurs in low numbers in a rather poor fauna which lacks, e.g., the woodland species. The lower part of this section might be the equivalent of section Mol. 1, which is clearly not the case for the upper part, as suggested by the occurrence here of i.a. *Physa fontinalis, Planorbis carinatus, Anisus vorticulus,* and *Corbicula fluminalis,* but more significantly by the very demanding land molluscs *Vertigo moulinsiana. Vallonia enniensis. Spermodea lamellata, Acanthinula aculeata, Vitrea contracta. Zonitoides sepultus, Clausilia bidentata,* and *Macrogastra plicatula.* Especially *Spermodea lamellata* indicates the presence of old woodland of the *Fago-Quercetum* type.

The molluscan succession is in general very much like that in sections Mol. 1-3.

Samples Mol. 5-6

Locally, lenses with large numbers of adult *Corbicula fluminalis* were found. Three samples have been studied. Unfortunately, sample Mol. 5 comprises mainly *Corbicula* shells sampled by hand. The other mollusc material was collected in the laboratory from the sediment still attached to the shells of *Corbicula.*

Mol. 6-I and 6-II are residues of samples collected for vertebrate research, which were briefly treated with a weak acid solution. Since this treatment led to the loss of many of the larger thin-walled and of the small shells, none of these residues reflect the initial fauna. For this reason Table 1 gives only presence or absence. The three samples contained 111, 157, and 52 specimens of *Corbicula.*

Although the faunas are incomplete, it is clear that they correlate with the middle and upper parts of the sections 2-4. This is indicated in particular by the occurrence of *Bithynia tentaculata.* The occurrence of *Planorbis carinatus* in the Mol. 6 sample also points to this conclusion. Mol. 6-II even correlates with the uppermost part of Mol. 3 and 4, as concluded from the occurrence of *Vertigo pusilla, V. substriata, Spermodea lamellata, Vitrea contracta, Clausilia bidentata,* and *Macrogastra plicatula.*

Sample Mol. 7

This sample was taken from the sediment around the skull of the Giant Deer, described by Van Kolfschoten (1985).

The occurrence of *Bithynia tentaculata, Planorbis carinatus, Pisidium casertanum, Vertigo pygmaea,* and *Vallonia enniensis* is shared with the upper part of sections Mol. 2 and Mol. 3. However, species present in the uppermost part of these sections, for instance *Vertigo pusilla, Vitrea contracta, Clausilia bidentata,* and *Macrogastra plicatula,* are missing. Thus, sample Mol. 7 fits well in the first half of the upper part of sections Mol. 2 and Mol. 3.

The palaeo-environment was marshy with a rather poor aquatic vegetation, and the *Bithynia* ratio points to a certain water-movement. Land molluscs are dominated by the hygrophiles, which is in accordance with the marshy habitat. In the terrestrial fauna in the strict sense the mesophiles and open-ground species are predominant, which is also expressed in a rather low forest ratio.

Samples Mol. 8-11

These samples were taken from subsided layers present in dolines. The faunas differ from the foregoing by a considerably higher number of woodland species. Among them are *Vertigo pusilla, V. substriata, Spermodea lamellata, Acanthinula aculeata,* Limacidae (large species), *Zonitoides sepultus, Clausilia bidentata,* and *Macrogastra plicatula.* Most of these species are present in the uppermost part of sections Mol. 3 and Mol. 4, and all of them are absent in sections Mol. 1 and Mol. 2.

Although there are some differences between the shares taken by the terrestrial ecological groups, the general pattern is only comparable with the uppermost part of Mol. 4. The values reached by the woodland group and the forest ratio belong to the highest found at Belvédère, giving evidence of a successional development that progressed further here than in most of the investigated sections. The assumption that a higher lying part of the beds of this succession did not undergo leaching, due to subsidence in an active doline, does not seem unreasonable.

The freshwater fauna shows a higher proportion of groups C and D than was usually found. The amounts agree well with those found for the upper part of section Mol. 4. Moreover, the numbers of vegetation-dwelling aquatic gastropods seem to be in accordance as well. This combination excludes a correlation with, e.g., the lower part of section Mol. 3. There C and D are similar to those found in the doline faunas, in contrast to the amounts of vegetation-dwelling aquatic gastropods, which are very low in section Mol. 3. The *Bithynia* ratios of the doline samples are rather low, in all cases lying below 50%. In sum, the freshwater fauna is most closely related to the fauna in the upper part of section Mol. 4, which is consistent with the picture found for the terrestrial fauna. In the doline samples the fresh-water faunas indicated a rather large, stagnant, well-vegetated body of water.

Noteworthy is the presence of *Pisidium casertanum* in all doline samples as well as in samples Mol. 6-I and 7 and the upper samples of sections Mol. 2, 3, and 4. Thus, this species apparently does not occur in the middle and lower parts of the sections. This seems to be a remarkable observation, because according to Kuijper (1985), the species behaves as a pioneer species. The reason for its late presence in Belvédère is not clear.

ECOLOGICAL DIAGRAMS OF SPECIES (see Fig. 3)

Comparison of freshwater ecological diagrams shows that only section Mol. 2 and part of Mol. 4 (samples 1-4) have a certain degree of resemblance. The diagrams of the other sections show hardly any similarity. In any case, it is clear that the share taken by each group in sections Mol. 2-4 is roughly the same, which indicates the absence of divergent ecological conditions.

Land molluscs can be compared only for sections Mol. 2 and 3, because the diagrams for the other sections are incomplete or lacking. Although the woodland diagrams in particular are not quite the same, the terrestrial faunas in the strict sense nevertheless show a similar pattern. The mesophiles have a minimum in the middle part of the sections; this minimum lies between more or less pronounced maxima and coincides with maxima of both woodland and open-ground species. The maximum of the woodland group lies between minima in both sections. It is clear that the development of the terrestrial fauna in the wider surroundings of both sections was very much the same. This is in accordance with the synchronism of sedimentation deduced from the diagrams of individuals.

CORRELATIONS WITHIN UNIT 4 BASED ON THE ECOLOGICAL DIAGRAMS

1 - Mol. 2 and 3 are of the same age; Mol. 1 is older.
2 - The lower part of Mol. 4 possibly correlates with Mol. 1; the upper part of the former section is a correlative of the uppermost part of Mol. 2 and 3. This also holds for Mol. 6-I and Mol. 8/11.
3 - Mol. 5, 6-II, and 7 correlate with the middle part of Mol. 2 and 3.

SEQUENTIAL ARRIVAL OF SPECIES

Comparison of the ecologically deduced time-correlations with the distribution of each species in the whole sequence shows the existance of some partly facies-independent levels of appearance of species. On these levels a zonation is defined, each zone being characterized by the first arrivals at its base. Accordingly five zones (A-E) have been distinguished. Table 1 shows for each species the zone in which it arrived for the first time.

Numbers of first arrivals in each zone are shown in Fig. 4 for land molluscs only. Fig. 5 shows a zonation scheme for all analysed sections and single samples.

CLIMATIC AND ECOLOGICAL DEVELOPMENT OF THE FAUNA IN UNIT 4

For each zone all species found were grouped ecologically and climatically. The resulting values are presented in a diagram (Fig. 6). From this diagram it becomes clear that the first half of a warm-temperate phase is represented within Unit 4. This may be elucidated by the following.

Species passing the arctic circle at present (group I) decline from 70 to 47%, and species staying south of that latitude (Group II) are only present from zone C upward, rising to 27%. Species today reaching at best the southernmost part of Scandinavia (group III) fluctuate between 25 and 37%. These values suggest either an increasing temperature or a stabilization of an already high temperature from zone A onward, leaving demanding species enough time to immigrate during the next zonal intervals. As can deduced from Gittenberger, Backhuijs and Ripken (1984), the climatic composition of the recent fauna living in the surroundings of the Belvédère site is as follows: group I: 37.7%, group II: 24.5%, and group III: 37.7%. At first sight the fauna of Belvédère seems to indicate a cooler climate than that prevailing today in the region. However, it must be kept in mind that the terrestrial fauna of the Belvédère site lived in the vicinity of water, which can exert a cooling effect on nearby habitats. Moreover, the recent values are an expression of the entire terrestrial fauna living in a relatively large area with a wide variety of habitats and where open water is of minor importance. Therefore, at least in the uppermost part of the sequence of Unit 4 the climatic conditions must have approximated those prevailing today.

The ratio between atlantic, continental, and indifferent species suggests a slightly more continental climate before zone D than after that time.

The climatic trends are well expressed in the ecological development of the terrestrial fauna. There is an almost linear increase of woodland species from zero in zone A to 48% in zone E, whereas open-ground species decrease at the same time from 58% in A to 18% in E. The hygrophiles show a development that could be expected from a more atlantic climate during deposition of the upper part of the sequence.

Seventy species are present in zone E. This absolute species number itself indicates an 'interglacial' status of the fauna. Some figures may serve to illustrate this: from Late Tiglian interglacial deposits exposed in the pit of Russel Tiglia near Tegelen, 54 species are known; from Bavel (Interglacial of Bavel): 87 species; Kanne, Valley of the Jeker (Holocene, Atlanticum): 70 species; Hekelingen (Holocene, Subboreal): 59 species (excluding small *Pisidium* species). The recent fauna living in the surroundings of Belvédère comprises 61 species. In The Netherlands Quaternary non-marine cool and cold climate faunas usually do not exceed 20 species.

It is difficult to give absolute data on the climate, but it may reasonably be assumed that from zone D upward annual rainfall was high, i.e., at least 800 mm (at present: less than 700 mm); the mean annual temperature was at least 10°C (today: 9.5-10°C); the mean July temperatures were certainly not lower than 15°C, but probably exceed 18°C (today: 17.5°C); mean January temperatures are more difficult to estimate but were certainly above 0°C (today: 2-2.5°C).

Since no new species belonging to the most demanding climate group appear in zone E, it is not unlikely that the climatic optimum had already been passed in that zone. This is supported by the presence of some species occurring in old woodland in this last zone, e.g., *Spermodea lamellata*. The *Lumbricus* evidence indicates that the climatic optimum was reached in zone D. Furthermore, it is noteworthy that a tortoise (*Emys orbicularis*) was found in the upper part of zone D of section Mol. 3 (Van Kolfschoten, 1985). This points strongly to mean July temperatures exceeding 17-18°C. The tortoise corroborates the conclusions drawn about the climate from the mollusc evidence.

The following characteristics can be given for the various zones:

Zones A and B: Relatively low number of species; few land species; open-ground species very important, whereas woodland species are absent or only present in low numbers. Climatic group II absent; continental climate group has its strongest expansion.

Zone A: Woodland and atlantic species absent; important first arrivals: *Bithynia troscheli, Gyraulus laevis, Deroceras agreste, Clausilia parvula,* and *Helicopsis striata.*

Zone B: Woodland and atlantic species are present now in low numbers; first maximum in climatic group III.

Important first arrival: *Cepaea nemoralis.*

Zone C: Number of species, land molluscs, woodland species, and hygrophiles all increase. Decrease of freshwater molluscs, open-ground species, and climatic group I; waterplant-dwelling gastropods reach a maximum, mesophiles show a very distinct peak. Climatic group II present in low numbers; continental climate group at its lowest

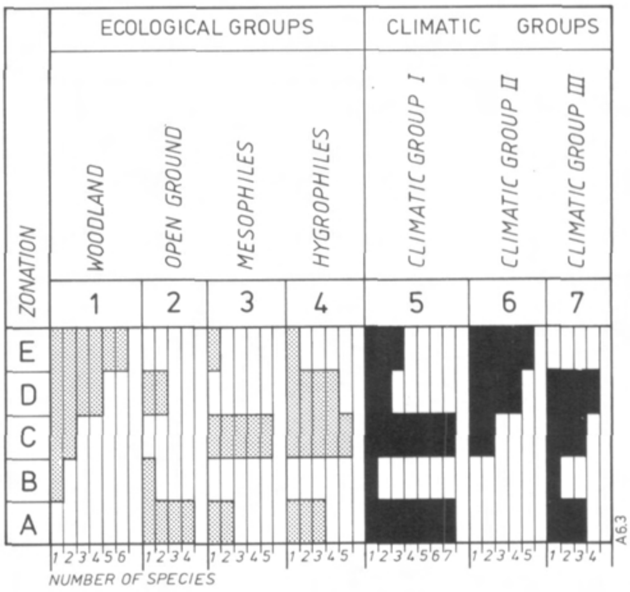


Fig. 4. Number of first arrivals of land-mollusc species in each zone grouped according to geological and climatic conditions.

expansion; minor minima shown by the open-ground species and climatic group III (cooler phase?). Important first arrivals: *Anisus vorticulus, Corbicula fluminalis, Carychium* cf. *mariae,* and *Vertigo moulinsiana.*

Zones D and E: High (increasing) number of species; similar trend shown by the land molluscs, the woodland species and climatic group II; freshwater molluscs, the mesophiles, and climatic group I decreasing.

Zone D: The hygrophiles have their strongest expansion; open-ground species reach a second maximum, as do climatic group III and the continental climate group; in this zone the last of the first arrivals in climatic group III take place. Very probably the climatic optimum was reached. Important first arrivals: *Bithynia tentaculata, Planorbis carinatus. Carychium tridentatum, Vallonia enniensis, Discus rotundatus, Zonitoides sepultus,* Milacidae, and *Cochlicopa nitens.*

Zone E: Maxima for the number of species, the land molluscs, the woodland species, and climatic group II. Minima for the freshwater molluscs, the open-ground species, the mesophiles, and climatic group I. The climatic group III is at its lowest expansion. Important first arrivals: *Segmentina nitida, Vertigo substriata, Spermodea lamellata, Acanthinula aculeata, Clausilia bidentata,* and *Macrogastra plicatula.*

ENVIRONMENT OF THE MAIN ARCHAEOLOGICAL HORIZON

Field evidence from the archaeological sites B and C (Roebroeks, 1985) indicates that the main archaeological horizon lies in sediments deposited in molluscan zones C, D and E. At most of the locations it was present in zone D. This means that the archaeological horizon from Unit 4 dates from the climatic optimum of the temperate phase in which the unit was deposited.

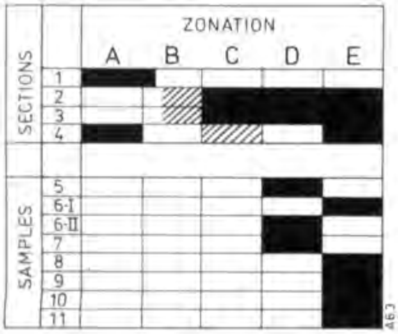


Fig. 5. Zones present in the sections and samples under discussion.

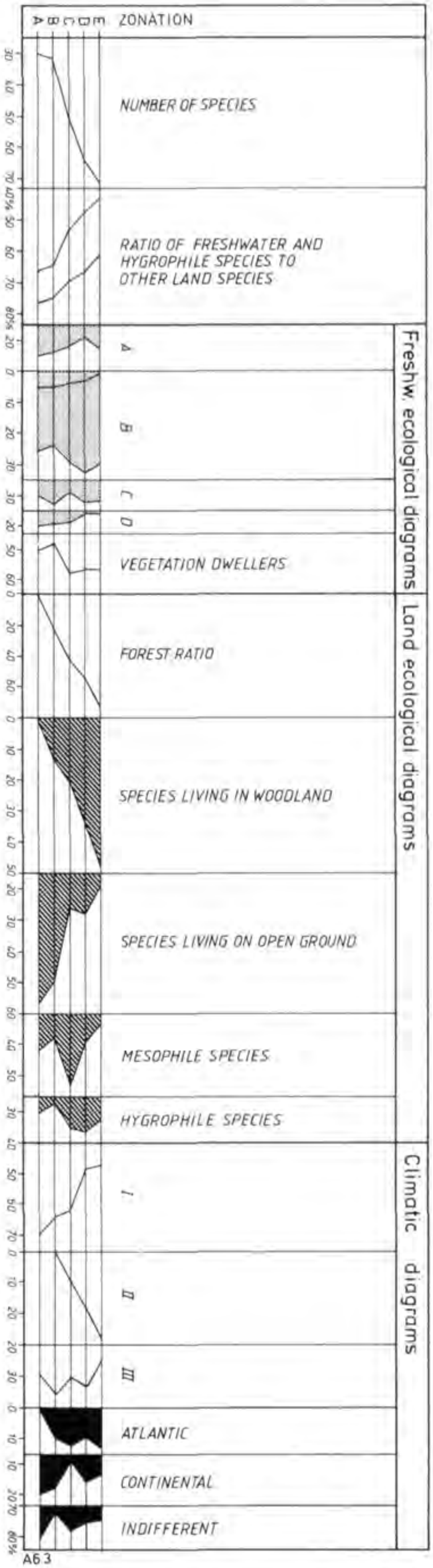


Fig. 6. Diagrams of species based on compilation of all species present in each zone.

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PLATE 1

Fig. 1. *Carychium tridentatum* (Risso, 1826): sample Mol. 6-I.

Fig. 2. *Carychium* cf *mariae* Paulucci, 1878: sample Mol. 6-I.

Fig. 3. *Carychium minimum* Müller, 1774: Middle Holocene channel deposits at Beveren Waes near Antwerp (Belgium).

The windows in the shells depicted in Figures 1-3 show the structure of the columellar apparatus. The development of the folds is depicted by showing the shell in three positions.

Fig. 4. Trace of predation on the shell of *Carychium* cf *mariae* Paulucci, 1878 (section Mol. 3, sample 3). Two irregular oval holes (black area) bordered by a zone where the upper shell layer has been removed (dotted area).

Fig. 5. Trace of predation on the shell of *Vertigo pygmaea* (Draparnaud, 1801) (section Mol. 3, sample 3). An irregular more or less oval area from which the upper shell layer has been removed. Straight longitudinal grooves, probably caused by rasping, are visible.

Fig. 6. Trace of predation on the shell of *Zonitoides nitidus* (Müller, 1774) (sample Mol. 10). Hole with irregular margins (black area) bordered by a zone lacking the upper shell layer (dotted area).

Fig. 7. *Cochlicopa nitens* (Gallenstein, 1848): sample Mol. 7.

Fig. 8. *Cochlicopa lubrica* (Müller, 1774): section Mol. 3, sample 1.

Fig. 9. *Cochlicopa lubricella* (Porro, 1838): sample Mol. 6-I.

The illustrated material is stored in the private collections of Mr. W. J. Kuijper (Noordwijk) (Figs. 6 & 7) and T. Meijer (Alkmaar) (Fig. 3), and the collection of the Geological Survey of The Netherlands (Haarlem) (Figs. 1, 2, 4, 5, 8, 9). The drawings were prepared by the author.

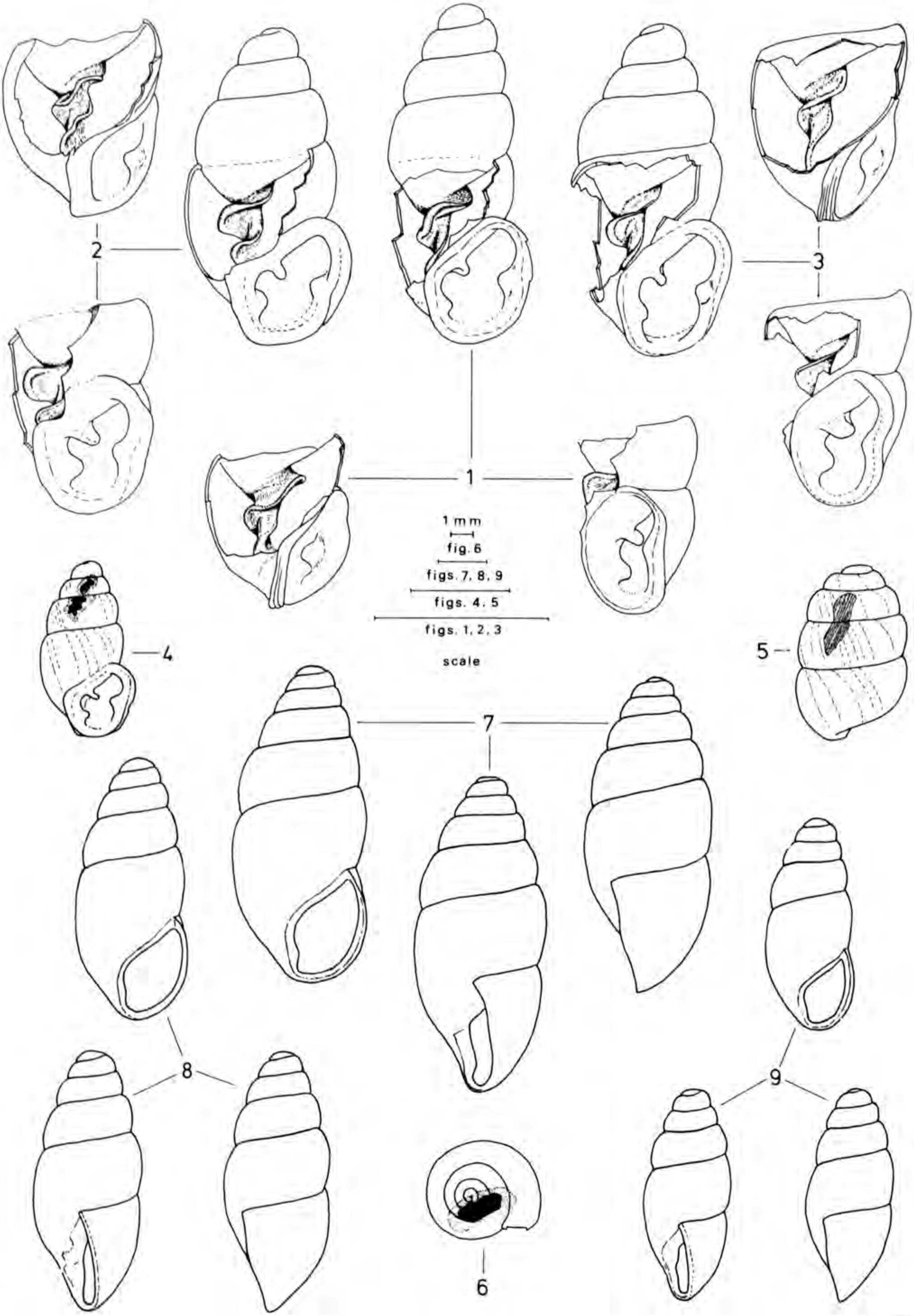
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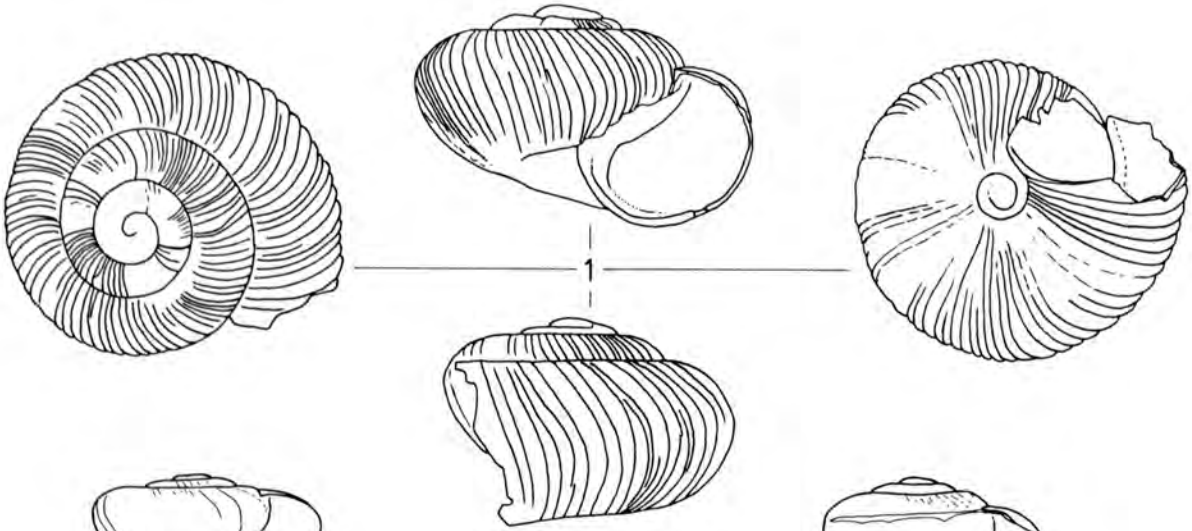
PLATE 2

Fig. 1. *Helicopsis striata* (Müller, 1774): undefined stratum in Unit 4 of the Belvédère sequence, not included in this study.
Fig. 2. *Zonitoides sepultus* Ložek, 1964: Zone E, present in a location which is not included in this study.
Fig. 3. *Zonitoides nitidus* (Müller, 1774): sample Mol. 6-I.
Fig. 4. *Milax* sp.: section Mol. 4, sample 6.
Fig. 5. and 6. Limacidae, small species: section Mol. 3, sample 4.
Fig. 7. *Deroceras agreste* (Linné, 1758): Zone A in a section lying parallel to section Mol. 1.
Fig. 8. Limacidae, large species: sample Mol. 11.
Fig. 9. Limacidae, small species: section Mol. 3, sample 3.

The illustrated material is stored in the private collection of Mr. W. J. Kuijper (Noordwijk) (Figs. 1, 4, 7, 8) and the collection of the Geological Survey of The Netherlands (Figs. 2, 3, 5, 6, 9). Drawings were prepared by the author.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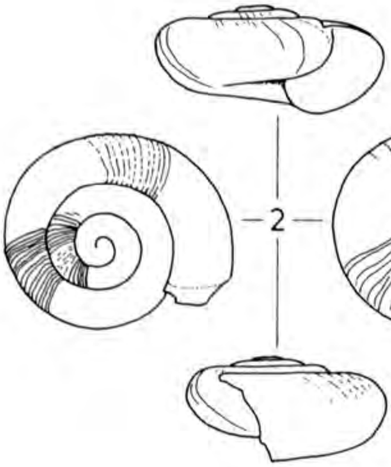
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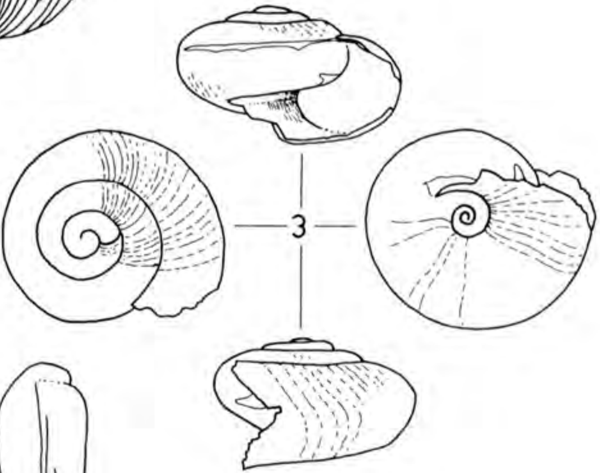
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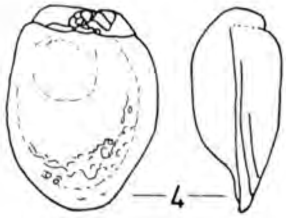
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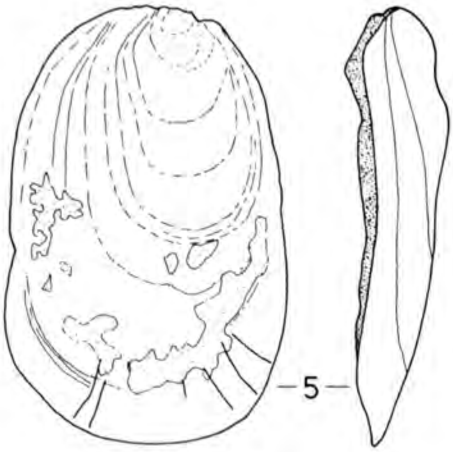
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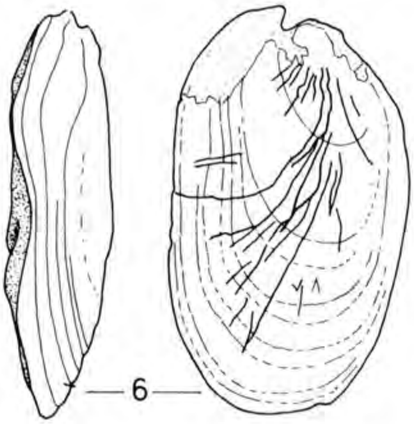
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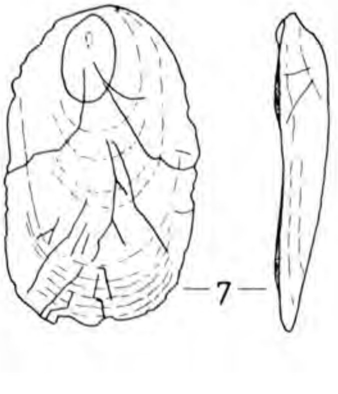
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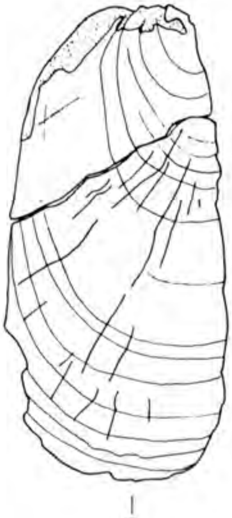
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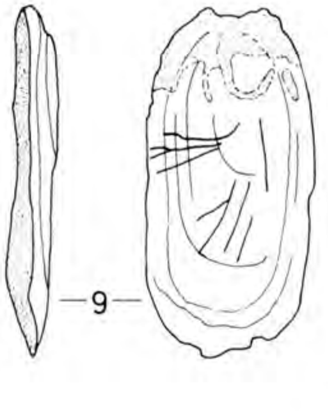
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MALACOLOGICAL RESEARCH OF WEICHSELIAN DEPOSITS AT THE MAASTRICHT-BELVÉDÈRE PIT

W. J. KUIJPER*

CONTENTS

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ABSTRACT

Four loess-samples from the base of the Weichselian deposits were collected during archaeological excavations in the Belvédère pit near Maastricht. The samples were analysed for their molluscan content. A characteristic loess fauna was found which was composed of seven landsnails (*Pupilla* – fauna) and eight aquatic species. The animals must have lived under periglacial conditions in a tundra-like landscape.

INTRODUCTION

The fauna discussed here was collected in 1983 and 1984 during the archeological excavations of site E (sample 1 and 2), between site G and C (sample 3) and near site G (sample 4). The situation of these areas is given by Roebroeks (1985). The shells were found at the base of the Weichselian loess deposits (= base unit 6). In the higher loess deposits molluscs were not present or were only found in small numbers. Vandenberghe et. al. (1985) give a description of the sediments in the pit.

Altogether about a half m³ of an up to 10 cm thick layer of red-brown, calcareous, fine-sandy loam was analysed (sample 1). From this layer at site E, at the base of the loess, bone and artefacts have also been collected. Sample 2, only 0,1 dm³, was taken from a small gravel layer in a deposit of 25 cm above the loam of sample 1. This layer consists of yellow-brown-grey, calcareous loess-loam. Sample 3 (circa 5 dm³) and 4 (circa 8 dm³) were situated two meters above the loess-base and were taken from a yellow, calcareous loess.

The samples were sieved with water. The fraction above 0,5 mm was analysed.

ACKNOWLEDGEMENTS

The author thanks K. Groenendijk, J. P. de Warrimont and T. van Kolfschoten for collecting the samples, T. Meijer for identification *Pisidium subtruncatum* and W. Roebroeks (the excavator) for giving additional information.

THE MOLLUSCS OF THE LOESS

The species found are noted in table 1.

species sample:	1	2	3	4
landsnails				
Pupilla muscorum (Linné, 1758)	xxx	xx	xxx	–
Limacidae "small"	xxx	–	x	–
Trichia hispida (Linné, 1758)	xx	x	1	–
Oxyloma cf elegans (Risso, 1826)	x	–	–	–
Vallonia costata (Müller, 1774)	3	–	–	–
Succinea oblonga Draparnaud, 1801	2	–	–	–
Helicigona arbustorum (Linné, 1758)	1	–	–	–
freshwater snails				
Gyraulus acronicus (Férrussac, 1807)	x	–	–	x
Stagnicola palustris (Müller, 1774)	x	–	–	x
Radix peregra (Müller, 1774)	x	–	–	–
Planorbis planorbis (Linné, 1758)	x	–	–	–
Galba truncatula (Müller, 1774)	16	–	–	–
Anisus leucostomus (Millet, 1813)	11	1	–	–
freshwater mussels				
Pisidium subtruncatum Malm, 1855	3	–	–	–
Pisidium obtusale lapponicum (Clessin, 1877)	2	–	–	–

Table 1. Maastricht-Belvédère. Molluscs from the base of the Weichselian loess.
x = tens, xx = hundreds, xxx = thousands.

The shells are mostly very well preserved. The combination of terrestrial and aquatic species in the same deposits (sample 1 and 2) proves that transport has played a role. I presume however that this has occurred over short distances within the same environment. In the deposit from which sample 3 and 4 were collected transport seems less important. Here the terrestrial and aquatic species are not mixed and also the tertiary molluscs are absent.

ENVIRONMENT

Table 1 shows that the landfauna is represented by seven and the freshwaterfauna by eight species. Firstly I will give a short summary of the habitat of these animals.

Pupilla muscorum is a small snail which can be often found in large numbers in extreme conditions. It lives under moist to very dry conditions in open landscapes. For example in grassland with an unstable surface. Limacidae "small" includes a group of small slugspecies. An identification based upon the plates is not really possible. Probably they belong to a species of *Deroceras*. These slugs live in all kinds of damp places. *Trichia hispida* and *Succinea oblonga* occur in a wide variety of vegetations: moist and dry, open and shaded. Also they can be found in quite different environments; from dry grassy places to moist woods. *Oxyloma elegans* is an animal which requires damp habitats, often living along water. *Vallonia costata* lives in a wide variety of habitats, for example marshy places, dry chalkgrasslands and woods, *Helicigona arbustorum* is most common in river valleys, but also lives along roadsides, under shrubs and, especially in cold areas, in open habitats. *Galba truncatula* lives in small, stagnant bodies of water, (chalk)marshes or on the damp mud at the margins of larger watercourses. Like *Anisus leucostomus,* an animal of small bodies of stagnant water and marshy banks, *Galba truncatula* can survive the drying up of its habitat. Both are characteristic for pools and banks which dry up periodically. *Stagnicola palustris* and *Radix peregra* can also survive periods of drought, but these two live also in deeper water or in the sluggish parts of rivers. *Gyraulus acronicus* and *Planorbis planorbis* live in sluggish and stagnant, generally plant rich waters of different dimensions. *Pisidium subtruncatum* can be found in quite different types of water. The tundra-form *lapponicum* of *Pisidium obtusale* occurs today in cold areas (N. America, N. Scandinavia, Siberia). The animals live in marshes and bogs in stagnant little pools, marshy banks, etc.

When we now consider the assemblage as a whole then the great number of shells of the landsnail *Pupilla muscorum* is especially striking. *Pupilla muscorum,* Limacidae and *Trichia hispida* together form the main part of the molluscan fauna. Besides the landsnails there is also a rather important aquatic component. From the former we conclude that the animals lived in an open area with low vegetation. It was damp and there were many shallow pools and marshy places which dried out periodically.

The combination of species and their frequency are characteristic for a fauna of the loess. Research into quaternary molluscan faunas has shown that those of the loess occupy a special place.

During the Weichselian they occur in extensive areas: an indication of a rather similar environment over a large part of Europe. The conditions during the loess development are not comparable with present day situations and point to an unique loessenvironment (Ložek, 1965). This environment is best comparable with the cold tundras of modern times.

All species tolerate extreme conditions very well. Their present day distribution in Europe reaches to or far beyond the polarcircle.

Also the toleration of coldness is high. The water species point to a wet environment. The occurrence of water on a loess-soil can be explained for example by the presence of permafrost.

Since the fauna of Belvédère is dominated by *Pupilla muscorum* it can be considered as a species-poor *Pupilla*-fauna. This type of fauna is in central Europe especially characteristic for the "Hochglazial" (Lozek, 1964: 139 and Mania, 1972: 116). But an occurrence in the cold phases of the early and late glacial however is also possible.

DATING

In the foregoing we have concluded that the molluscan fauna must have lived in a cold phases of the Weichselian. Therefore this fauna is not very suitable for dating. By other observations it is possible to give an indication about the age. The four samples were collected from deposits under the "Horizont van Nagelbeek" (Haesaerts et al., 1981). The age of this horizon is about 20.000 years. In association with the molluscs, mammal remains were collected in sample 1. According to Van Kolfschoten (1985) this fauna lived in the early Weichselian. A conclusion based on, amongst other factors, the evolutionary stage of *Dicrostonyx torquatus* (lemming).

OTHER OBSERVATIONS

Besides the molluscs mentioned in the samples other shells and non-molluscan remains were found (table 2).

sample:	1	2	3	4
tertiary shells	xx	—	—	—
earthworms (Lumbricidae)	xxx	x	xxx	x
ostracods	x	x	—	—
mammals, birds	see Van Kolfschoten, 1985			

Table 2. Maastricht-Belvédère. Non-molluscan fauna of the base of the Weichselian loess. Legend: see table 1.

The large number of tertiary shells is remarkable. The material is in a poor condition. These shells originate from marine deposits which were formed during the Oligocene (Oude Biezen). The deposits from this period can be found, for example, a short distance west of the Belvédère in Belgium. These shell-containing deposits are still being eroded by streams today (pers. comm. A. W. Janssen, RGM, Leiden). Therefore it is possible that sediment transport by water occurred during certain periods of the Weichselian.

SUMMARY

The base of the loess in the Belvédère contains a molluscan fauna which is characteristic for loess. The fauna points to periglacial conditions. The landsnails lived in a chalkrich, damp, open landscape with low vegetation. The aquatic animals lived in shallow pools and marshy places. Periodically parts of these dried out. Water provides some movement of the shells. The environment would be somewhat comparable with that of the present day tundras in northern Europe.

Dating by the molluscs is not possible. An age of Middle Weichselian as well as Early or Late Weichselian (within a cold phase) is possible.

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ARCHAEOLOGICAL RESEARCH AT THE MAASTRICHT-BELVÉDÈRE PIT; A REVIEW

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CONTENTS

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ABSTRACT

The Middle- and Late Pleistocene deposits in the Maastricht-Belvédère loess- and gravel pit have been the subject of intensive archaeological and geological research. In this paper the archaeology is reviewed. Archaeological materials have been found in 7 different stratigraphic levels. The finegrained fluviatile sediments of Unit 4 contained the well preserved remains of a site situated on a river-bank levee; in the flint assemblage, associated with a rich fauna of warm-temperate character, the Levallois-technique is represented. According to the biostratigraphical evidence the Unit 4 finds can be dated to pre-Eemian/post-Holsteinian warm temperate phase. Burned flints from Site C of Unit 4 yielded a TL age of 270 ± 22 ka.

At the base of Unit 6 (Weichselian loess) artifacts have been recovered in geological association with a rich fauna indicating a tundra environment. Biostratigraphical analysis of the fauna indicates an early Weichselian age.

INTRODUCTION

As set out above (Roebroeks, 1985) some preliminary papers on the archaeology of the site already have been published (Roebroeks, et al., 1983; Roebroeks 1984). In this volume of the Mededelingen Rijks Geologische Dienst this paper, like the previous ones, can only give a short review of some aspects of the archaeology of the site. This topic will be detailed extensively in a forthcoming monograph. (Roebroeks, in prep.).

In the following, the archaeology of the different stratigraphical units will be reviewed, beginning with the lowermost unit, Unit 3, the gravels. Attention will be drawn to the position of the archaeological assemblages in the K-cycles discerned by Mücher (Mücher, 1985). As Mücher discusses, Butler's (1959) K-cycle concept divides the Quaternary into stable periods, dominated by soil formation, and unstable periods dominated by erosion and the formation of slopes and slope deposits in sediment producing areas and by sedimentation in sediment-receiving areas.

THE ARCHAEOLOGY OF THE DIFFERENT UNITS

From the time of the first investigations in the pit onwards, the sites discovered and/or excavated were named according to their geographical position in the pit (Pit East, South, etc.). After several years of fieldwork this system does not work anymore and we have decided to name the different sites in alphabetical order corresponding to their date of discovery. Table 1 (see also fig. 1) gives a review of the different sites, their position in the lithostratigraphical Units established by Vandenberghe et al., (1985), etc.

	Fieldname	Unit	Excavated area	
SITE A	Pit East I	Unit 5.2	5 m² (1)	March 1981
SITE B	Pit North	Unit 4/5.2	19/23 m²	July-Sept. 1981
SITE C	Pit South	Unit 4	264 m²	1981-1983
SITE D	Pit East II	Unit 5.2	– – (1)	August 1982
SITE E	Pit WG	Unit 6	40 m²	Nov-Dec 1982
SITE F	Pit East III	Unit 4	42 m²	June-July 1984
SITE G	198411-12	Unit 4	15 m² (1)	Nov-Dec 1984

(1) Mainly (rescue-)collecting from sections and small trenches

Table 1: Review of the Maastricht-Belvédère Sites.

UNIT 3

From Unit 3, the gravels, comes only one "certain" artifact, a heavily rolled flake, found by Werner M. Felder, State Geological Survey, Heerlen (fig. 2). Despite intensive investigation no other certain artifacts have been collected from Unit 3. A severely rolled flake, found in one of the gravel layers present at the lower part of Unit 4, the terrace sands, however, probably derives from the lower laying gravels too.

UNIT 4

By the end of 1984 three excavations had taken place in this unit (formerly A2); an area of 264 m² (Site C) was excavated from 1981 to 1983; to the North of Site C 19 m² (Site B) was excavated in 1981, while Site F is placed in this unit too.

In addition to the excavations sections were recorded and a number of small trenches, one of which exposed Site G.

The archaeology of the sites C, B and F will be briefly reviewed, and then be related to an environmental reconstruction based on the research of Van Kolfschoten (1985) and Meijer (1985). The dating evidence for the assemblages preserved in Unit 4 will be discussed at the end of this paragraph.

Unit 4: Site C

At Site C (fig. 1) an area of 264 m² was excavated in three campaigns from 1981-1983. All find locations, including lithic debris smaller than 0.5 cm. were recorded three-dimensionally. The excavation recovered ca 3000 flint artifacts, bone material, charcaol and hematite.

The flint material consists mainly of small debris, ca 75% being less than 2 cm in length. Only three "tools", artifacts showing intentional retouch, have been found.

In the flint assemblage Levallois-flakes and some prepared cores are present (fig. 3,4 and 5). Both hard-hammer and soft-hammer flaking techniques seem to have been used. A high percentage of the butts is facetted (Index Facettage 50.4, Index Facettage stricte 43.7).

Spatially, there were three concentrations of finds, each with its own type and scatter of flint. The conjoining of the lithic debris accomplished so far (ca 20% of all artifacts recovered) does not point to any interrelation between these three concentrations; each of the (three or more) blocks of flint has its own spatially separate scatter.

Among the badly preserved faunal material from Site C Van Kolfschoten (1985) could identify milk-teeth of a young rhinoceros (*Dicerorhinus hemitoechus*), a deer vertebrate whose size approximates that

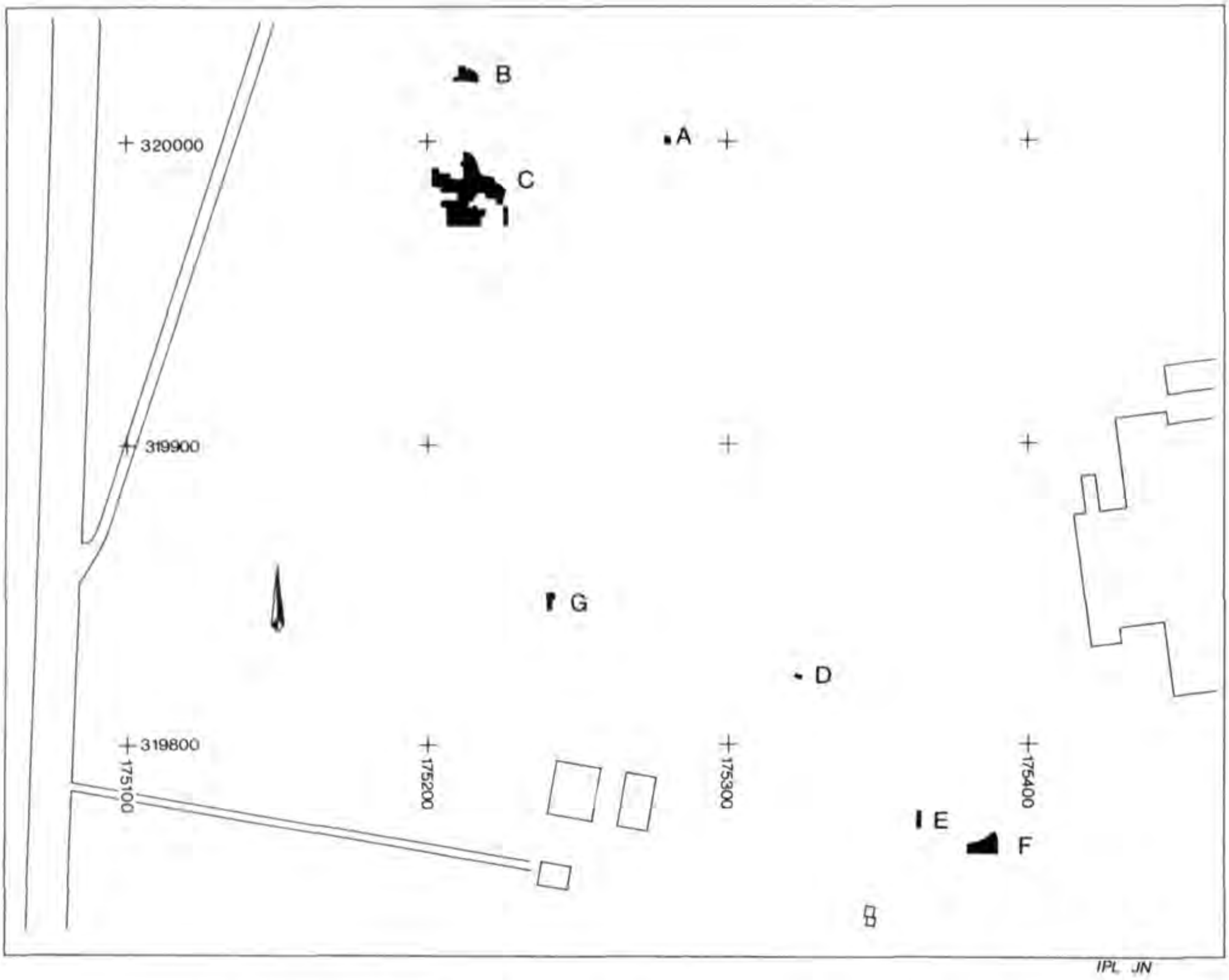

Fig. 1. Location of the Sites in the Belvédère-pit mentioned in the text. Scale 1:2500

of red deer, and the tibia of a large deer, probably *Cervus (Megaceros) giganteus*. In the western part of the excavation a charcaol concentration was found having an ovaloid shape of ca 2 by 3 m. The locations of ca 6000 tiny particles of charcoal, most of which are smaller than 2 mm, were recorded three-dimensionally.

Sixty of these have been identified at the Labor für Quartäre Hölzer (Birmensdorf, CH) as wood from deciduous species while eight of them could be more precisely identified as ash, *Fraxinus* sp. (W. Schoch, pers. comm., 1983).

Using Roentgen-diffraction analysis, reddish material surrounding pieces of compacted fine sand grains were identified as hematite (Arps, Heijnen & Roebroeks, in prep.). The hematite seems to have been partly dissolved, and then redeposited around the sand grains. All of the pieces recovered are 1 cm or less in size. Since hematite does not occur in the soil unit, it must have been intentionally transported. A probable source is one of the iron ore deposits south of Namur in the Belgian Maas valley, approximately 75 km SW of Maastricht (Horsch & Keesman, 1982; Bakels, pers. comm. 1983).

Inferences about prehistoric behavior based on the archaeological material from Site C are in part dependent upon our understanding of the site formation processes which affected the archaeological assemblage. Micromorphological research of the sediments shows that the fluvial deposition of the fine-grained

Fig. 2. Rolled flake from the gravels (Unit 3). Scale 1:1.

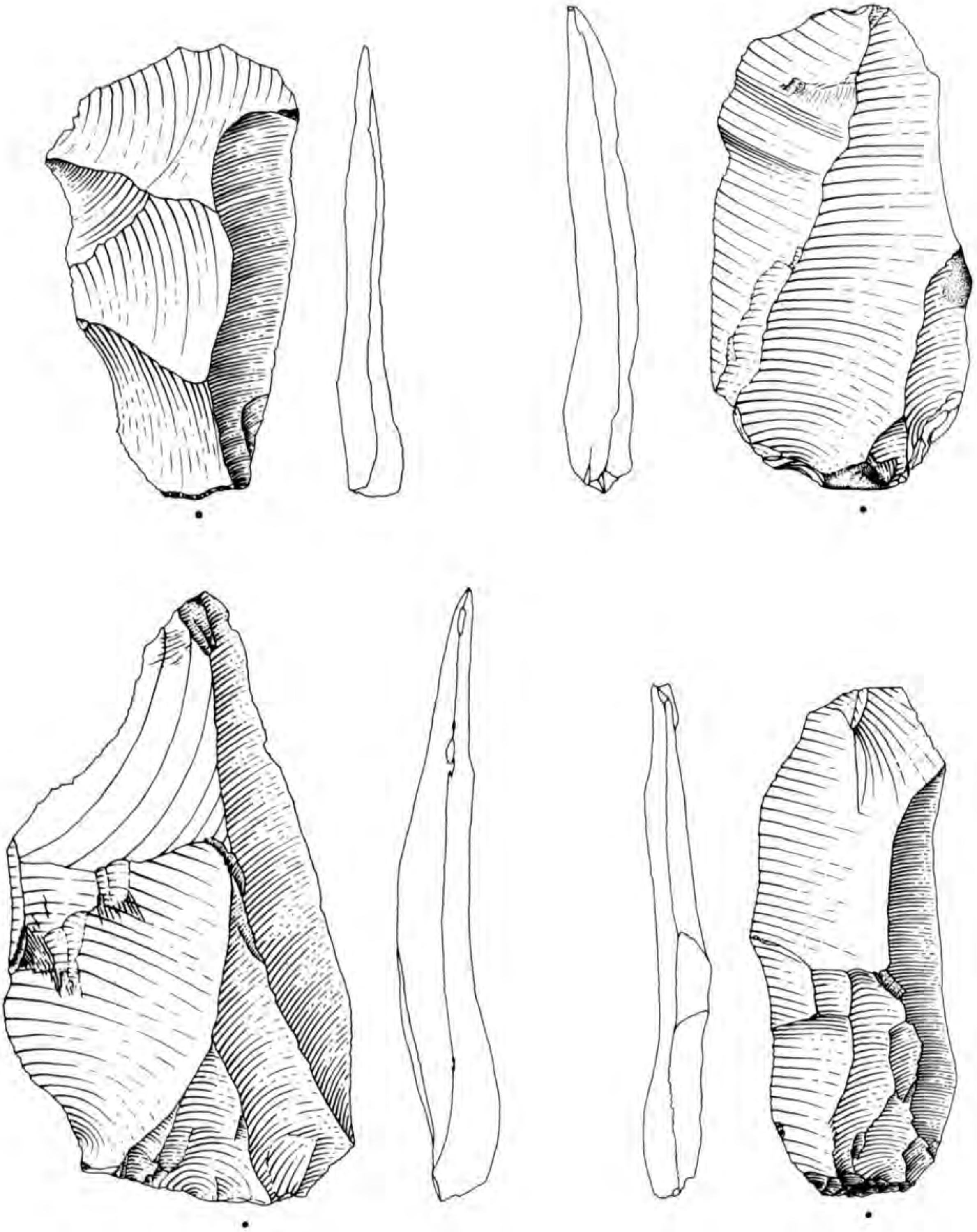

Fig. 3. Unit 4: Site C, Flakes. Scale 1:1.

sediment burying the cultural debris took place very calmly and gradually. The faunal analysis shows that there was a rich carpet of vegetation at the site which would have limited lateral displacement of the cultural remains. The low velocity of the aquaeous flow together with the vegetational obstacles seem to have minimized winnowing and repattering of archaeological debris. This assessment is supported by the distribution of the archaeological material: the spatial distribution of the small debris generally follows that of the larger pieces, while members of conjoined sets tend to be found in close proximity.

The complex site formation processes which affected the site will be discussed elsewhere in detail. Here

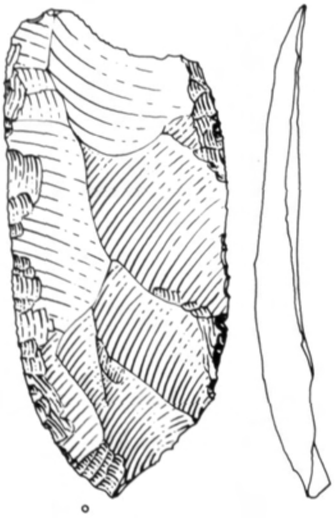

Fig. 4. Unit 4 Site C, Side-scraper. Scale 1:1.

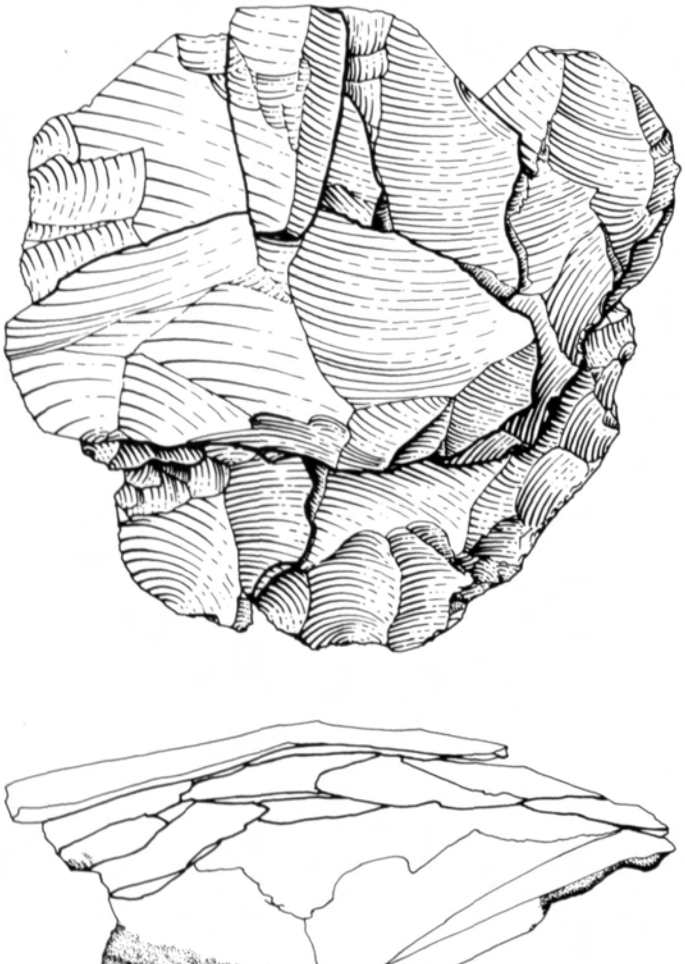

Fig. 5. Unit 4: Site C, Prepared core, with refitted flakes. Scale 1:1.

it suffices to state that karstification, which probably occurred in an early part of the Weichselian, caused a gradual subsiding of parts of the site, but did not disturb the horizontal arrangement of the archaeological material in the excavated areas. The limits of the excavated area however are determined by these karst phenomena which locally severely disturbed the sediments containing the artifacts.

Concluding, there are good reasons to infer that the archaeological material from Site C is in "primary archaeological context", i.e. that the grouping and the deposition of much of the debris is due primarily to human activities (cf. Isaac, 1967: 32).

Unit 4: Site B

30 M to the North of Site C 19 m² of Unit 4b were excavated in 1981. In the loams only 5 flakes were found in the excavation and a dozen in cleaning the large sections in the immediate neighbourhood of the site. One of these displayed a weak meat-polish (A. van Gijn, pers. comm. 1983). One flake, found in a section near Pit B, could be refitted with a tiny flake found in Site B.

In the eastern part of Site B, and in sections East of this site, the calcareous loams delivered us remains of *Cervus elaphus,* in association with the flakes mentioned. The red deer died when it was about a half year old, i.e. at the end of the autumn or during the first part of the winter (van Kolfschoten, 1985).

Unit 4: Site F

The position of the Site F assemblage in the stratigraphical units established by Vandenberghe et al. (1985) has been much discussed; in the 1984 field campaign the sediments containing the assemblage were correlated with the Unit 4 sediments of Site C, awaiting the results of laboratory analysis. Neither granulometrical nor micromorphological analysis however did succeed in placing the archaeological assemblage in one of the units and/or K-cycles discussed above (Mücher, pers. comm. 1985). This can very probably be attributed to the fact that Site F is situated at the top of the infilling of a channel which cut into the Unit 3 gravels; a vertical plotting of the artifacts showed that a slight depression still existed during the formation of the archeological assemblage. The Site F finds were made clearly below the gravel layer present at the base of Unit 5.2. Based on our field observations Site F is placed in Unit 4. This interpretation is not contradicted by a TL age determination of a burnt flint from the site, which shows that from the TL point of view there is no significant difference between this burnt artifact and other flints found in Unit 4 (Huxtable & Aitken, 1985).

At Site F 42 m² were excavated, and ca 1200 artifacts were recovered, ca 75% of which (as in Site C) are smaller than 2 cm in length. The flakes have been struck (generally by hard-hammer technique) in a much more primitive way than at Site C (fig. 6). Core preparation and the facetting of butts, clearly present at Site C, are almost completely absent in the Site F assemblage (Index Facettage 0.15, Index Facettage stricte 0.05). No clearly retouched tools have been found. According to a preliminary micro-wear analysis of a sample of the very fresh flakes present none of the artifacts have been used on hard material (A. van Gijn, pers. comm., 1985). The refitting of the artifacts seems to indicate that the assemblage might have been subjected to only a slight horizontal displacement.

At Site F no faunal material was recovered. A few burnt flints and some fragments of charcoal indicate the presence of a fire. Provisionally, Site F must be interpreted as a site containing the remains of a brief period of flint knapping. The site is interesting because its technology is "archaic" as compared to the "contemporaneous" Site C: strictly speaking, the Site F assemblage should be called "Lower Palaeolithic" (cf. Bosinski, 1982; Tuffreau, 1982).

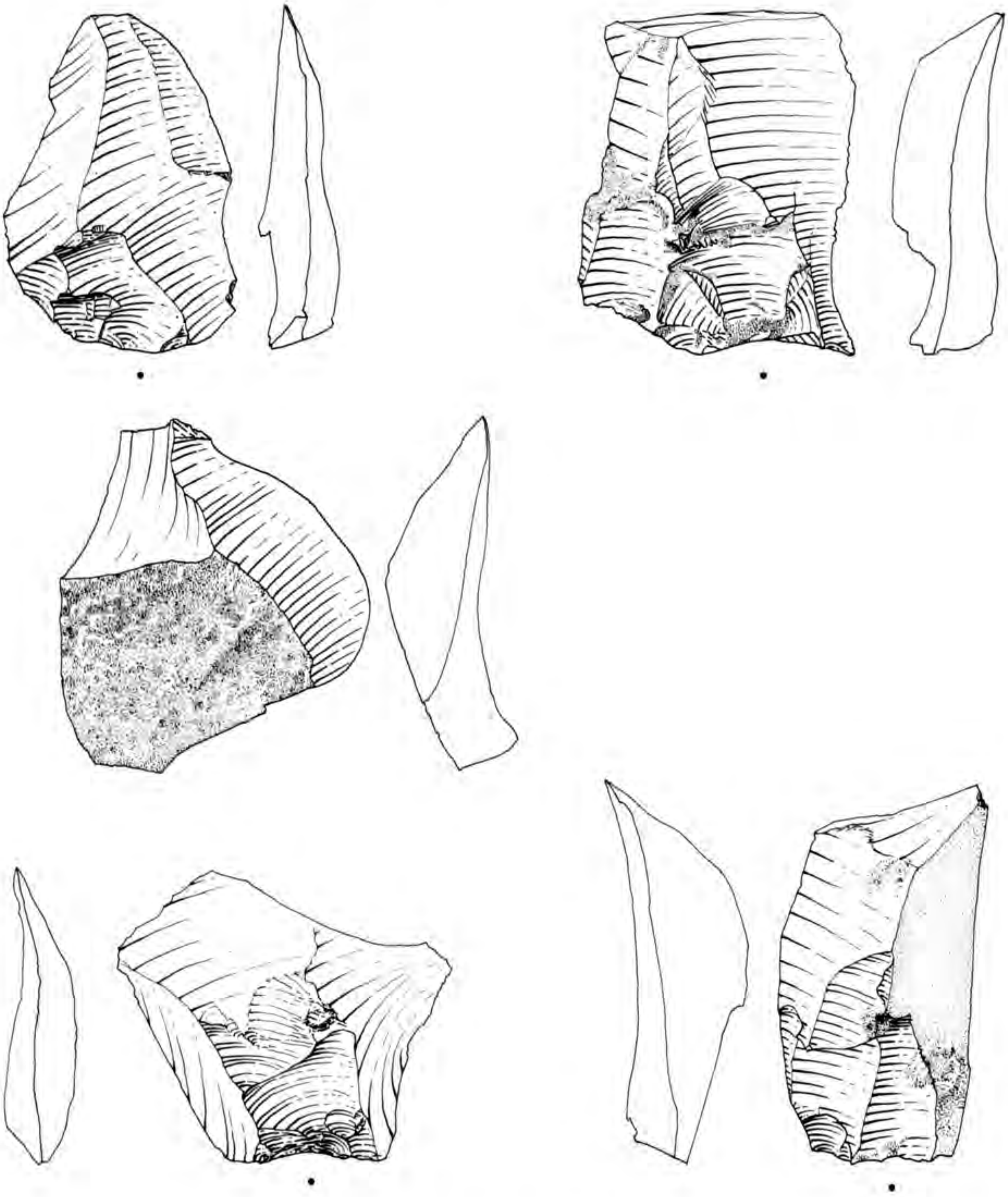

Fig. 6. Unit 4; Site F, Artifacts. Scale 1:1.

Unit 4: Environment

As can be deduced from the articles of Van Kolfschoten (1985) and Meijer (1985), considerable information has been collected about the environment in which palaeolithic people discarded the archaeological remains reviewed above.

Faunal remains collected from the fine-grained fluviatile deposits (Unit 4) indicate that warm-temperate conditions prevailed during the formation of these deposits. More than 70 species of aquatic and terrestrial molluscs have been identified by Meijer. Van Kolfschoten's study of the vertebrate fauna corrobates the image of "interglacial" conditions during deposition of the sediments; the fauna comprises several fish species, a tortoise (*Emys orbicularis*), a bird, four different species of shrew mice, a squirrel, five other rodents, hedgehog, elephant, rhinoceros, a giant deer, red deer and roe deer.

One of the sections sampled for malacological analysis was situated at the northeastern part of Site C (see: Meijer, 1985): the northern part of Site C, with a very low artifact density, must have been covered by (some) water constantly. The rest of the site was drier, but surrounded by moist to very wet depressions. At higher elevations the riverbank was populated with shade-giving vegetation. Further away from the riverbank the molluscan assemblage indicates a deciduous forest. Earthworm fossils indicate a thick soil vegetation of grasses and herbs in the open terrain and dense undergrowth in the forested areas.

The malacological analysis furthermore shows that the human occupation at Site C took place well after the beginning of the warm-temperate phase in which the Unit 4 sediments were deposited, more specifically in the climatic optimum of this warm temperate phase (Meijer, 1985).

Unit 4: Dating

In addition to its geological association with the next-to-youngest Middle Terrace of the river Maas the age of Unit 4 and the associated archaeological and faunal remains has been assessed by means of biostratigraphy (van Kolfschoten, 1985) and the TL dating technique (Huxtable & Aitken, 1985).

Van Kolfschoten's research allows us to place the Unit 4 assemblages in a warm-temperate phase between the Holsteinian interglacial and the advance of the Saalian ice-sheet in the Central Netherlands. M. J. Aitken and J. Huxtable have made an independent assessment of the age of this warm-temperate phase with the TL dating technique, applied on burned flints from Unit 4. Their preliminary age determination gives the Unit 4 assemblages an age of 270 ± 22 ka (Huxtable & Aitken, 1985).

Discussion Unit 4

The environment depicted above must have been very attractive to the palaeolithic hunter-gatherers: abundant raw materials for tools, plenty of fresh water and a variety of fish species for food in the river, rhino's, deer and elephants grazing on the floodplain or in the nearby scrubs and forests. The marshy terrain must have been an ideal location for hunting larger animals, which could be driven into the immobilizing mire. Site C, where only a limited number of bones has been found, may have functioned as a place where animals, killed nearby, were partially processed and then taken away to a "base-camp". The spatial distribution of the artifacts and the large number of un- or hardly utilized flakes indicate that the occupation of the site was probably of very short duration. The Site B finds represent activities related to Site C or the remains of another visit to this region, equally attested by the flintknapping activities at Site F. That palaeolithic people were frequent visitors to the region during the deposition of Unit 4 sediments was demonstrated again at the end of 1984, when at Site G, most of which had been destroyed by quarrying activities, 15 m² could be "excavated": five artifacts (including the sidescraper illustrated in fig. 7) were found in association with very well preserved bone fragments, some charcoal flecks and two burned flints. Amongst the faunal remains – well preserved because of the presence of the calcareous Unit 4c on top of the finegrained Maas deposits – Van Kolfschoten identified rhinoceros and deer. The results of the 1985 excavation at Site G have not been incorporated in this article.

UNIT 5

Unit 5.1.

Sofar only isolated flakes have been found in Unit 5.1. Unit 5.1 was deposited after erosion of paleosol I, in the instable phase of the second K-cycle (Vandenberghe et al., 1985, Mücher, 1985).

Unit 5.2.

The sedimentation of the loams of Unit 5.2. – on top

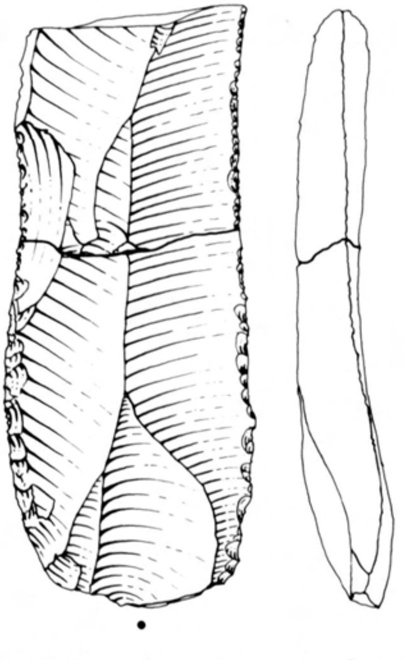

Fig. 7. Unit 4: Site G, Side-scraper. Scale 1:1.

of which paleosol III has developed – started with the erosion of Palaeosol II, followed by the deposition of a gravel layer, which also covered the eroded Palaeosol II at Site B (Mücher, 1985).

From the gravel layer at Site B and at several other places in the Belvédère pit several dozens of artifacts were collected including a Levallois-point, – flakes and a prepared core. At Site B the gravel layer yielded some faunal remains, including *Emys orbicularis.*

The gravel layer very probably contains remains of hunter-gatherer visits to the region made in the stable phase of the second K-cycle, or earlier.

Site A and D yielded artifacts which according to their spatial arrangement were deposited after deposition of the gravel layer mentioned above. At the level where the Site A and D assemblages were present, a horizon of grayish "mottles" could be seen (Vlekkenzone) which contrary to earlier opinions (Modderman & Roebroeks, 1981) is now considered to be a post-sedimentary phenomenon and thus cannot be used for making stratigraphical correlations in the pit.

A small sampling trench (Site A) produced ca 70 artifacts, a number of which could be refitted. Among the artifacts were flakes and blades produced with the Levallois-technique. Another small concentration of flakes (Site D) could only be recorded from section finds.

So far no faunal material has been recorded from this level. The two concentrations may be interpreted as small knapping sites.

In the middle and upper parts of Unit 5.2 only a few artifacts have been found; during the excavation of Site C, within an area of ca. 3 m² four flakes were recorded ca 30 cm above the basal gravel layer of Unit 5.2. Visually the flakes are made from raw material different from that of the underlying Site C assemblages, and none of them could be refitted to materials from Unit 4. Since the presence of the flakes in Unit 5.2 cannot be accounted for by vertical migration from a lower level, another "archaeological horizon" has been stipulated, for which there is other support. While cleaning a section near Site C in 1983, the author found a flake in the middle of Unit 5.2, while in January 1984 J.P. de Warrimont found an artifact in the same stratigraphical position in the neighbourhood of Site G.

According to Mücher (1985), the Unit 5.2 "loams" surfaces must have dried out periodically because mud crust fragments are present in the deposits.

UNIT 6: SITE E

A number of stray finds have been collected at the base of Unit 6, i.e. the base of the Weichselian loessic deposits. In a rescue excavation at the end of 1982 an area of ca 40 m² was sampled at the base of Unit 6, recovering ca 100 artifacts and a rich fauna (Site E). The find layer, consisting of a 5-25 cm thick sandy loam, which can only tentatively be correlated with the sub-units of 6.2, was locally covered by Unit 6.3. sediments, on top of which the Horizon of Nagelbeek (Haesaerts et al., 1981) was present.

The artifact assemblage contains some Levallois debitage and the top of a handaxe, probably broken during manufacture (fig. 8). The fauna found during the archaeological research contains a large number of animal species (see Van Kolfschoten, 1985, and Kuijper, 1985). Among the megafauna mammoth (*Mammuthus primigenius*), woolly rhinoceros (*Coelodonta antiquitatis*), horse (*Equus sp.*), reindeer (*Rangifer tarandus*), deer (*Cervus* sp.) and *Bos primigenius/Bison priscus* are present. The flint and faunal assemblages were found immediately on top of Unit 5.2., and were covered by laminated silt loams, probably derived from pleniglacial loess (Unit 6.3.). The maximum vertical dispersion of the materials is ca 25 cm, but because their matrix consists of redeposited sediments, we cannot be certain about the association between artifacts and faunal remains. Because the artifacts show no sign of transport and a number can be refitted, however, one might stipulate that their displacement has been limited. According to palaeontological assessment, several faunal fragments belong undoubtedly to one individual and several bone fragments could be refitted. The faunal assemblage shows no signs of considerable transport either. A metapode of a young *Equus* sp., found in the immediate neighbourhood of Site E during the excavation of Site F, shows signs which may be interpreted

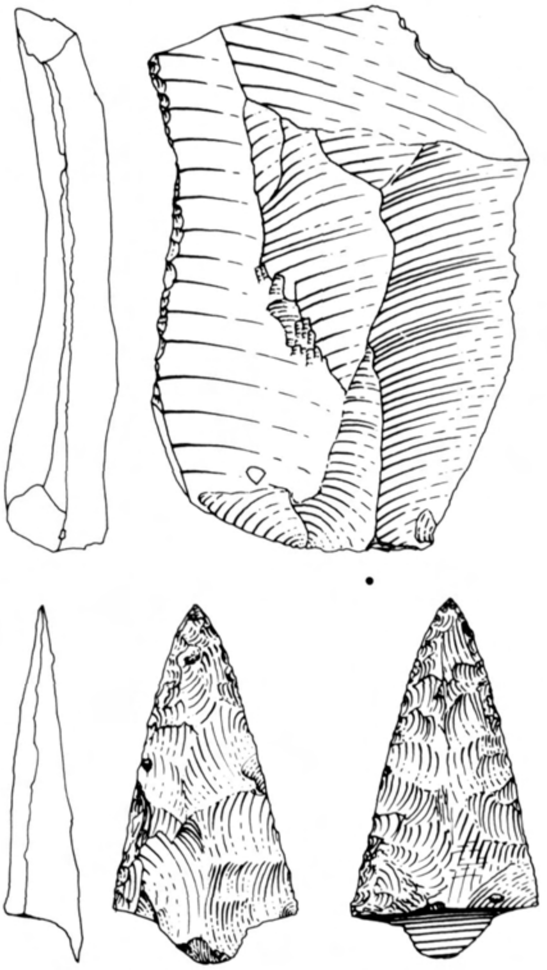

Fig. 8. Unit 6: Site E, Top of a pointed handaxe; retouched Levallois-flake. Scale 1:1.

as caused by human working (see also Van Kolfschoten, 1985).

Given this assessment, the predominance of young individuals among the megafauna allows us to infer that at least some of the faunal remains are associated with the stone implements and therefore represent a portion of the toolmaker's diet.

Provisionally the archaeological assemblage of Site E is interpreted as the product of one or more visits of late Middle Palaeolithic people to the border of the Middle Terrace of the Maas. The activities of these groups are, according to the current synthesis of the faunal analysis (molluscs: Kuijper, 1985; mammals: Van Kolfschoten, 1985) to be placed in a tundra-like environment. According to Van Kolfschoten the fauna has to be placed in an early part of the Weichselian.

According to Meijs (1985) however, in view of the heavy mineral content of the matrix of the archaeological and faunal assemblage, sedimentation of the find layer took place in the Middle Weichselian. In 1983 at Kesselt (Belgium), ca 4.5 km west of Belvédère, a site comparable to site E was discovered by members of the Belvédère working group, and subsequently excavated by the Catholic University of Leuven (Lauwers & Meijs, 1985).

Higher up in Unit 6.3 a few heavily patinated flakes have been collected from an erosion level below the Horizon of Nagelbeek

CONCLUSIONS

The archaeological research, conducted by the Institute of Prehistory of Leiden University, of the quaternary deposits in the Maastricht-Belvédère pit has uncovered a relatively rich series of archaeological and faunal remains.

In 7 different stratigraphical positions cultural remains have been found, occasionally associated with faunal remains.

At least part of the rich faunal assemblage found at Site E, at the base of Unit 6, is interpreted as representing a portion of the diet of the hunter-gatherers who produced the Middle Palaeolithic flint assemblage found at Site E. Palaeontological assessment of the fauna indicates a Early Weichselian age for the formation of the archaeological assemblage.

The most important lithostratigraphic unit, both from the archaeological and the palaeontological point of view, is Unit 4, in which Site C was situated. The faunal assemblage from Unit 4 and the TL dating of burned flints from this unit places the Middle Palaeolithic industry from Site C clearly in a pre-Eemian warm-temperate phase, in the 270 ±22 ka time range.

The data collected from Unit 4 enable us to reconstruct the environment as well as the behaviour of early Middle Palaeolithic groups.

In recent years several sites have been published from the same time range as Belvédère Unit 4. In the Netherlands, for instance, the rich sites in the neighbourhood of Rhenen, discovered in the 1970-s by the amateur-archaeologists Franssen and Wouters (1978; Stapert, 1981) were formed before the arrival of the Saalian ice sheet. The Belgian site of Mesvin (Cahen & Haesaerts, 1984) is to be placed in about the same chronological context, just like layer 1 of the German site Ariendorf, Neuwieder Becken (Turner, in press).

Only a few of these "pre-Eemian" sites, however, can be considered to be in primary archaeological context. Of this last category Bilzingsleben (German Democratic Republic) is considered older than the Maastricht-Belvédère Unit 4 sites, because *Arvicola cantiana* is present at Bilzingsleben, whereas the more evolved *A. cantiana/terrestris* occurs in Maastricht-Belvédère Unit 4 (van Kolfschoten, 1985).

According to the "*Arvicola*-line" Biache St. Vaast (Northern France) should be younger than the Maastricht-Belvédère Unit 4 sites, although the presence of *A. terrestris* is documented at Biache only by one element (A. Tuffreau, pers. comm. 1984). Corroborating evidence, however, comes from the TL age of Biache. Aitken et al. (in press.) place the site at 175 ± 13 ka.

The *Arvicola's* present in the faunal assemblage from the Lower Travertines of the prolific site Ehringsdorf (German Democratic Republic) enabled Van Kolfschoten (1985) to place the Lower Travertines in between Bilzingsleben and Biache St. Vaast, in the same relative position as the Maastricht-Belvédère Unit 4 sites.

Fig. 9 gives a schematic of the chronological relations of the sites discussed above together with the site of La Cotte St. Brelade, layers C and D: (OxTL 238 ±35 ka cf. Callow, in press).

Contrary to the sites mentioned above, the Unit 4 sediments at Maastricht-Belvédère contain very fine grained (sensu: Binford, 1982) cultural assemblages, produced during a brief period of activity, rarely documented in Lower and Middle Palaeolithic archaeology.

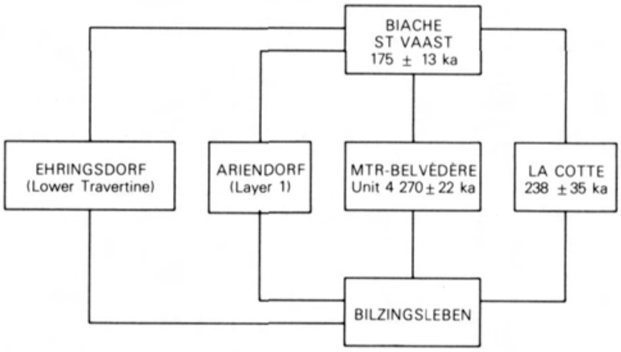

Fig. 9. Diagram of the chronological relationships of the archaeological sites Ariendorf (Layer 1), Biache St. Vaast, Ehringsdorf (Lower Travertine), Bilzingsleben, La Cotte St. Brelade (layers C and D) and Maastricht-Belvédère (Unit 4). The schematic is based on the biostratigraphy of the *Arvicola* line (van Kolfschoten, 1985) and Oxford TL dating of burned flints (Aitken et al., in press.).

ACKNOWLEDGEMENTS

For the realization of this article I owe a great debt to K. Groenendijk, P. Hennekens and J. P. de Warrimont for their constant help and stimulating discussions. T. van Kolfschoten and H. J. Mücher read and made constructive comments on earlier drafts of this paper. J. Nederlof prepared the illustrations, while S. Loving edited the English text. The research could not have taken place without financial support from the Netherlands Organization for the Advancement of Pure Research (Archon Dissertation Grant 123-21-007), the Municipal Service for Archaeological Research Maastricht and the Province of Limburg. Mr. F. Blom, the manager of the mining operations in the pit, is to be thanked for his cooperation and permission to excavate.

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THE MAASTRICHT-BELVÉDÈRE PROJECT: AN INTERMEDIATE SYNTHESIS

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INTRODUCTION

In this volume of the Mededelingen Rijks Geologische Dienst a synthetic review of the Belvédère research is presented. This should be regarded as an interim publication of the ideas on the stratigraphy, palaeoenvironment and the archaeology of the site. These ideas are based on many discussions between scientists from several disciplines, which took place mainly during the joint fieldwork in the years 1980-1985.

The Maastricht-Belvédère research is still continuing and new results can be expected in the near future; a monograph dealing with the archaeology of the site is in preparation.

In this article we briefly review the results of the Quaternary research conducted at the site, mention some unsolved problems and indicate future investigations. Following a discussion of the Pleistocene Belvédère sequence special attention is given to the faunal and archaeological assemblages from Unit 4 and their place in the N.W. European stratigraphy.

THE MAASTRICHT-BELVÉDÈRE SEQUENCE

Unit 3: the Unit 3 gravels were deposited on the Palaeocene chalk subsoil (Unit 1), which is locally covered by Tertiary sands (Unit 2). From their sedimentary structure the Unit 3 gravels are interpreted as deposited by a braided river system (Vandenberghe et al., 1985). According to palaeontological assessment of mammal fossils collected from the upper part of the gravels the deposition took place in a post-Holsteinian cold phase (van Kolfschoten, 1985)*. From Unit 3 comes only one 'certain' artifact, found in the upper half.

Unit 4: in the Unit 4 'terrace sands' several facies are present, (Vandenberghe et al., 1985): in general, a fining upwards sequence can be observed in the Unit 4 fluviatile deposits, but lateral transitions in grain size frequently occur, from sand (4a) to loam (4b) deposits. At the upper part of Unit 4 locally a calcareous tufa occurs. In the top of Unit 4 remnants of a truncated Luvisol ('Parabraunerde') are present.

According to Van Kolfschoten (1985) and Meijer (1985) a climate transition took place during the deposition of the Unit 4 sediments: the lowermost parts of Unit 4 yielded fossils which indicate a more continental climate, while higher upwards in the sequence mammal and molluscan faunas strongly indicating a humid warm phase of interglacial signature have been recovered. The middle palaeolithic flint assemblages from the different Unit 4 sites in the pit were all situated in the upper part of Unit 4; the major site, Site C, has to be placed in the climate optimum of this interglacial (Roebroeks, 1985).

According to palaeontological assessment of the mammal fauna Unit 4 was deposited in a warm-temperate phase before the advance of the Saalian-glaciers in The Netherlands (van Kolfschoten, 1985), while according to Meijer (1985) the molluscan assemblage from Unit 4 has to be dated in an interglacial stage between the Holsteinian and the Eemian. For the time being this interglacial stage may best be correlated with the 'warm' Hoogeveen interstadial (Zagwijn, 1973).

Unit 4 is further discussed in the next paragraph.

Unit 5: this unit consists of two subunits

Unit 5.1. a mixture of sands and loam, is interpreted as consisting of solifluction deposits formed under humid conditions with seasonal frozen ground and poor vegetation. On top of this subunit remnants of either a weakly developed or heavily truncated soil are present (Mücher, 1985). Only a few isolated flakes have been found in Unit 5.1. Whether this unit represents a distinct climatic cycle, or reflects a period of (local) instability in the palaeo-landscape is not clear at this moment.

Unit 5.2: this subunit consists essentially of redeposited loess material, which according to its heavy mineral association dates from a pre-Weichselian period (Meijs, 1985). On top remnants of a Luvisol ('Parabraunerde') are present; this palaeosol is correlated with the Eemian 'Sol de Rocourt' (Gullentops, 1954). Redeposited faunal elements and flint artifacts have been found in a pebble-layer at the base of Unit 5.2., while at site A a small concentration of flakes and blades produced in the Levallois-technique was found.

Unit 6: this unit consists mainly of redeposited loessic material and can be divided in 4 subunits (see Vandenberghe et al., 1985) Unit 6.1 (the base of Unit 6) consists of a dark humic layer, interpreted as a truncated steppe soil. On top of it, locally pebble zones occur (Unit 6.2), generally covered by fine laminated silt loams (Unit 6.3). Unit 6.4 consists of a calcareous loessic deposit on top of which the cryoturbated Nagelbeek Horizon (Haesaerts et al., 1981) is present.

A rich faunal assemblage was collected in association with flint artifacts at the base of Unit 6, below Unit 6.3 (Site E). The faunal remains from Site E indicate a tundra environment and have to be placed in a cold stage (Van Kolfschoten, 1985; Kuijper, 1985). According to Van Kolfschoten (1985) the fauna dates from an early part of the Weichselian.

Unit 7: this unit represents a typical loess deposit of the Weichselian Pleniglacial, on top of which the Holocene Luvisol is present. According to sediment dating (TL) Unit 7 has an average age of 17.5 ± 3.5 ka (Huxtable & Aitken, 1985).

THE STRATIGRAPHICAL POSITION OF UNIT 4 AND ITS ABSOLUTE AGE

There are several current approaches to date the Unit

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* note: this interpretation, however, has to be confronted with a recent find (summer 1985) of a loamy layer with leave imprints and a 'temperate' molluscan fauna in the middle of Unit 3 (see Meijer, 1985 Addendum). This find and the sedimentary structure of the particular profile suggests a bipartition of Unit 3, meaning that the gravel may have been deposited in at least two cold cycles. Work on this problem is continuing.

4 deposits. In this volume Huxtable and Aitken (1985) have published a TL age determination of 7 burnt flints from Unit 4: 270 ± 22 ka (OxTL 712k). This is in satisfactory agreement with a provisional ESR age determination on molluscs from Unit 4: 220 ± 40 ka (pers. comm. R. Grün & O. Katzenberger, Köln, 1985).

These dates indicate - independently from the biostratigraphical evidence - that the warm-temperate phase documented in Unit 4 has to be placed well before the Eemian interglacial period. Biostratigraphical analysis furthermore places the faunal assemblages from Unit 4 after the Holsteinian interglacial.

There are a number of palaeolithic sites in Northern Europe which we interpret as having about the same age as the Maastricht-Belvédère Unit 4 assemblages. One of the most well-known is Ehringsdorf (German Democratic Republic), where the Lower Travertines yielded a nearly identical fauna (van Kolfschoten, 1985); U-S dates for the Lower Travertines adjacent to the 'Brandschichten' give an average age of 225 ± 26 ka (Cook et al., 1982).

Oxford TL age determination of burnt flints from layers C and D from La Cotte St. Brelade (Jersey, United Kingdom) place the archeological assemblages from these layers in the 238 ± 35 ka time range (Callow, 1985). Based on the absolute age determinations the Maastricht-Belvédère Unit 4 assemblages might be older than the sites mentioned above, but clearly in the same stratigraphical range.

The faunal assemblage from findlayer 1 at Ariendorf (Western Germany) indicates that the assemblage was formed in a cold stage either just before or just after the Maastricht-Belvédère Unit 4 warm-temperate phase (Turner, in press; van Kolfschoten, 1985).

On biostratigraphical evidence the sites of Bilzingsleben (German Democratic Republic) and Miesenheim (Western Germany) are to be placed in an earlier warm-temperate phase (van Kolfschoten, 1985). For Bilzingsleben several dates have been published ranging from 228 + 17 ka - 12 ka (Harmon et al., 1980) to ages greater than 350 ka (Cook et al., 1982).

Evidently younger than Maastricht-Belvédère Unit 4 is the site of Biache St. Vaast, both on biostratigraphical grounds (Chaline, 1978; van Kolfschoten, 1985) as on Oxford TL age determination: 175 ± 13 ka (Aitken et al., 1985).

CONCLUDING REMARKS

The Quaternary sequence at the Maastricht-Belvédère pit contains several artifact- and fossil bearing horizons: the most important one indicates the presence of a major climate oscillation of interglacial character within the Saalian of the Netherlands. The rich faunal assemblages found in association with primary context remains of human activities give the Maastricht-Belvédère Unit 4 sites an important place in the North European quaternary research, dated by two independent lines of evidence, biostratigraphical analysis and chronometric dating.

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