2 The geology of the Belvédère pit and its wider geographical setting
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2.1 Introduction

The aim of this chapter is to give a short description of the Middle and Late Pleistocene deposits at Maastricht-Belvédère in order to provide the reader with a general geological framework, certain aspects of which will be discussed in greater detail in the rest of this volume. Before we concentrate our attention on the Belvédère-pit, a description will be given of the general geological setting of the Quaternary deposits at Belvédère in a summary of the geology of the region, i.e. the southern part of the Dutch province of Limburg (2.2). The paragraphs following this regional setting discuss the lithology and lithostratigraphy of the recorded sections in the pit (2.3.2), the palaeosols present (2.3.3), and the palaeoenvironment during the formation of the deposits (2.3.4). Finally, the relative and absolute dating evidence of the different units is presented in section 2.3.5, while section 2.3.6 gives a first synthesis of the Middle Pleistocene sequence at Belvédère.

2.2 The wider geological setting

South Limburg is situated in the transitional fault-block area between the Dutch *Central Graben* and the Ardennes highlands, as shown in figure 7. The continuation of the *Central Graben* into Germany is called the *Rurtal Graben* (fig. 7). In general terms, the Ardennes Massif may be seen as an erosional area, while the *Central Graben* is a depositional environment. In South Limburg there are a large number of southeast/northwest orientated faults, of which the northernmost *Feldbiss* fault is the most pronounced. In the south, the *Central Graben* is bounded by the *Feldbiss* fault and in the north by the *Peelrand* fault. These faults developed during the Early Tertiary and have affected the geography of sedimentation and erosion in South Limburg ever since.

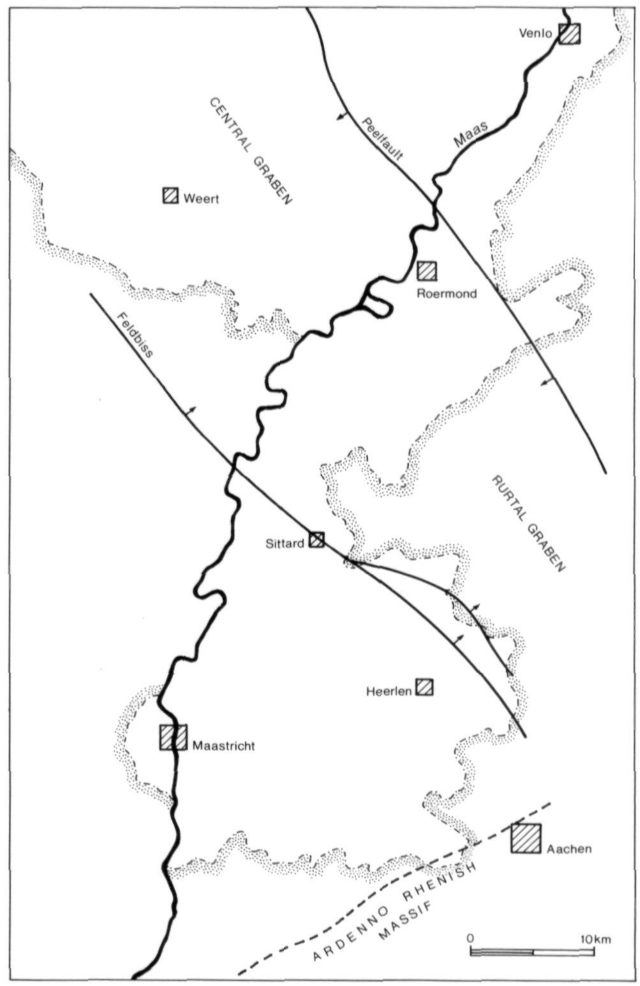

Fig. 7. Structural development of South Limburg (after: Kuyl 1980).

The subsoil deposits of the South Limburg area date from the Carboniferous, Cretaceous and Tertiary periods and are overlain by Quaternary deposits, which consist mainly of fluviatile sediments and loess.

The present-day landscape of South Limburg was sculptured during the Quaternary by the Maas and its tributaries. By the end of the Tertiary a peneplain had formed over the Ardennes and their immediate surroundings. Traces of this peneplain are still visible in the southeastern part of South Limburg; more extensive remnants occur in the neighbouring Belgian and German uplands. The highest hill in the Netherlands, the Vaalserberg, 321 m above Dutch Ordnance Level (NAP), is a slight elevation in the peneplain.

In the Early Quaternary the Maas took a more northeasterly course than at present (called the East Maas) from a point near Liège where it left the Ardennes to join the

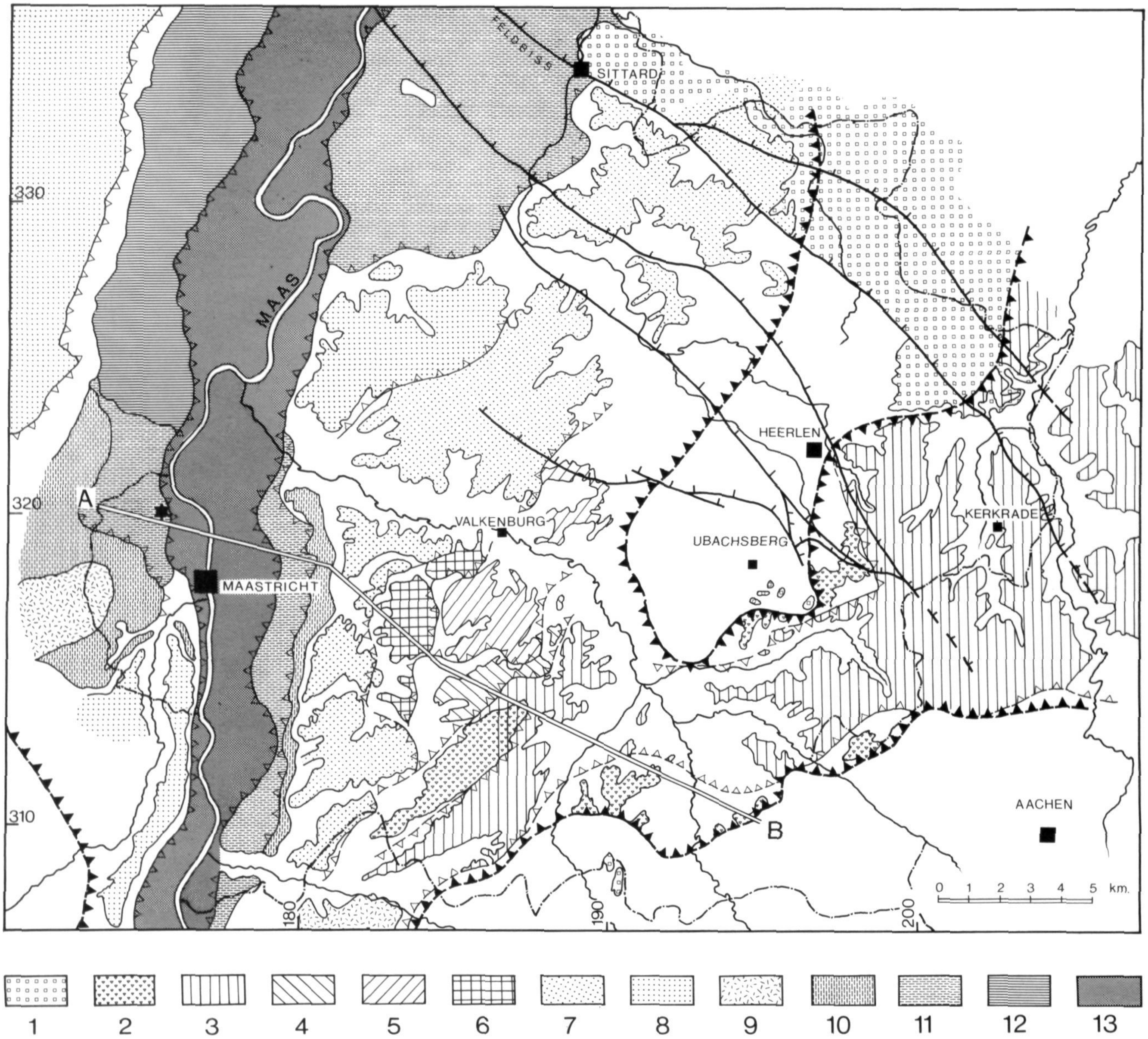

Fig. 8. The Maas terrace geomorphology of South Limburg; drawing based on data provided by the State Geological Survey at Heerlen (pers. comm. P.W. Bosch and W.M. Felder, 1980-1985). The numbers refer to the symbols used for the different terrace bodies: 1=Waubach (Tertiary deposits), 2=Kosberg, 3=Simpelveld, 4=Margraten, 5=Sibbe, 6=Valkenburg, 7=St.Geertruid, 8=St.Pietersberg, 9='s Gravenvoeren, 10=Rothem, 11=Caberg, 12=Eisden-Lanklaar, 13=Oost-Maarland. See also Table 2. (The position of the Belvédère pit is indicated by an asterisk.) The A-B line refers to the cross-section shown in figure 9.

Rhine in the environs of the town of Jülich (West Germany). A wide and shallow valley was formed in the peneplain, traces of which are still visible in the landscape (Kuyl 1980).

During the later Quaternary a series of river terraces was formed along the Maas in South Limburg; the most complete series is found to the south of the *Central Graben*. The terrace formation was related to the epirogenetic upheaval of the southeastern part of South Limburg, which began during the Early Pleistocene and eventually caused the river to shift its northeasterly course to a more westerly one, called the West Maas. After every change of course, the river cut deeper into the landscape, leaving behind the old river deposits as elevated terraces. The older the Maas sediments, the higher they lie south of the Feldbiss fault.

The terrace system of the Maas, traditionally divided into Higher, Middle and Lower Terraces with several subdivisions, has been the object of much research (Brueren 1945;

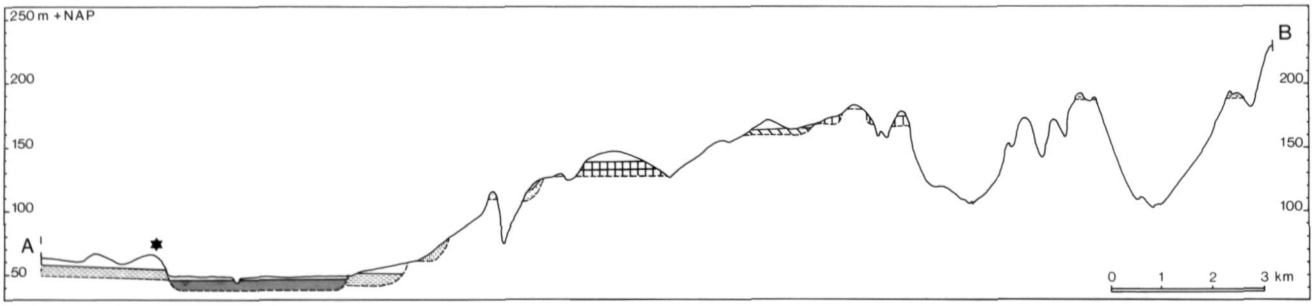

Fig. 9. Cross-section through the terrace landscape of South Limburg, along the A-B line indicated in figure 8. For the symbols used for the terrace bodies see figure 8 (after: Brueren 1945). The position of the Belvédère pit is indicated by an asterisk.

Van Straaten 1946; Zonneveld 1955; Paulissen 1973; Doppert *et al.* 1975; Felder *et al.* 1980; Kuyl 1980). The nomenclature of the terrace sequence now in use is shown in table 2. Figure 8 shows the terrace geomorphology of South Limburg based on new maps recently provided by the State Geological Survey (W.M. Felder and P. Bosch, pers. comm., 1980-1985). The new results differ only slightly from the results of Brueren (1945), on which the cross-sections through the terrace landscape shown in figure 9 are based.

Evidence concerning the ages of the different terraces is still scarce (table 2). The few biostratigraphical data available have been summarized by Zagwijn (1985). Pollen analysis of a sample from a peat bed discovered in the uppermost part of the Simpelveld Higher Terrace deposits suggests a Late Tiglian date for the formation of these sediments (Platte Bosschen locality). Sediments of the Valkenburg Higher Terrace at Süsterseel are overlain by a loess deposit with reversed magnetic polarity (Van Montfrans 1971), and pollen analysis of a peat bed found at the boundary between the terrace gravel and the overlying loess indicates that the peat was formed during the Bavel interglacial of the Early Pleistocene and thus has an age of 900 ka (Zagwijn/De Jong 1983-1984).

Finally, gravels of the Caberg Middle Terrace deposits at Maastricht-Belvédère are overlain by sediments whose faunal contents indicate that they were formed in an intra-Saalian warm-temperate phase (section 8.3 of this volume; see also: Van Kolfschoten/Roebroeks 1985). The gravels themselves contain the remains of a cold fauna, which have been assigned an Early Saalian age (Van Kolfschoten 1985).

In addition to this biostratigraphical evidence, Bruins (1980) has found (unpublished) indications of the presence of the Brunhes-Matuyama boundary in the Sint-Geertruid deposits at Nagelbeek. Paulissen (1973) identified a Middle Terrace younger than the Caberg terrace, but still dating from the Saalian, showing that a typical Eemian Interglacial soil had developed in the Eisden-Lanklaar terrace deposits.

The available data suggest that the fluviatile sedimentary sequence south of the *Central Graben* represents only a few episodes of the total stratigraphical time range of the Quaternary (Zagwijn 1985).

In the *Central Graben* itself sedimentation was more continuous than in the region south of the Feldbiss, where sedimentation alternated with erosion. In fact, the sedimentary sequence preserved in the *Central Graben* provides the most complete sequence of the Dutch Quaternary known. Quaternary sediments in this region are over 200 m thick in places (cf. Zagwijn/De Jong 1983-1984).

In the later part of the Pleistocene South Limburg was covered by loess deposits, which today vary in thickness from a few dm to more than 20 m. Figure 10 (after: Kuyl 1980) gives the distribution of loess deposits of over 5 m thick in South Limburg. In recent years the loess deposits in this region have been the object of detailed research, using physical and chemical methods developed for the earth sciences, such as thephrostratigraphy, micromorphology and thermoluminescence (TL) dating (cf. Juvigné 1977; Meijs 1980; Kuyl 1980; Vreeken/Mücher 1981; Haesaerts *et*

Table 2: The Pleistocene terrace sequence in South Limburg, with indications of the ages of the terraces as discussed in the text.

general subdivision	name	age
Lower Terrace	Oost-Maarland	
Middle Terrace	Eisden-Lanklaar	Late Saalian
	Caberg	Early Saalian
	Rothem	
	s'Gravenvoeren	
Higher Terrace	St Pietersberg	
	St Geertruid	Brunhes-Matuyama?
	Valkenburg	Bavel interglacial
	Sibbe	
	Margraten	
	Simpelveld	Late Tiglian
	Kosberg	

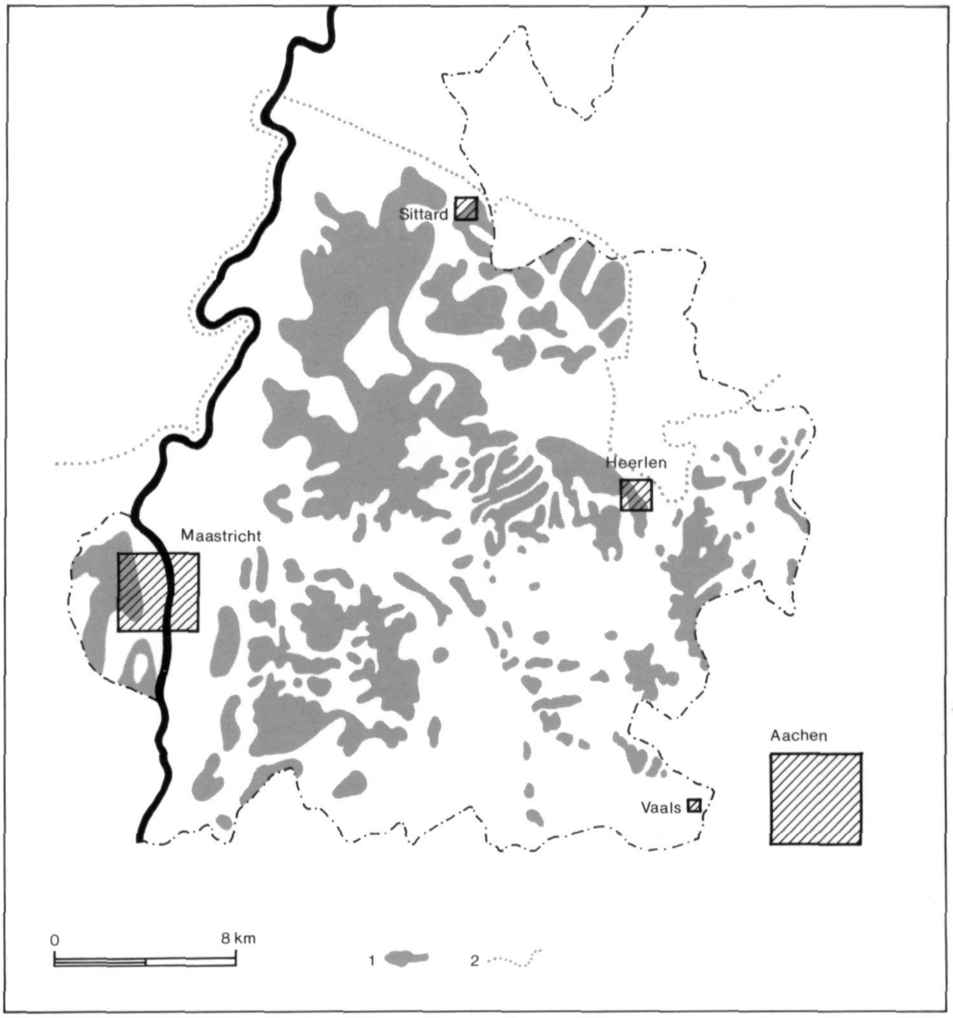

Fig. 10. Distribution of loess layers of over 5 metres thick (1) and the northern boundary of the loess (2) in South Limburg (after: Kuyl 1980).

al. 1981; Juvigné/Semmel 1981; Meijs *et al.* 1983; Mees/Meijs 1984; Meijs 1985; Vandenberghe *et al.* 1985; Huxtable/Aitken 1985; Bouten *et al.* 1985; Wintle 1987).

There are three diagnostic horizons in the loess stratigraphy of the region:

– the *Sol de Rocourt* (Gullentops 1954), interpreted as (remnants of) a soil of Eemian age, which was formed in Saalian loess;

– the *Eltville tuff*, a thin volcanic ash bed present in the toppart of the Weichselian 'Middle Silt Loam' (cf. Juvigné/Semmel 1981; Vreeken/Mücher 1981; Meijs *et al.* 1983). This layer has an estimated age of 20 ka (Haesaerts *et al.* 1981)

– the *Horizon of Nagelbeek* (Haesaerts *et al.* 1981), present above the Eltville tuff layer, and interpreted as a weakly developed 'tundra soil'.

The accidented South Limburg landscape seen today was, to a large extent, formed during the Pleistocene by the Maas and its tributaries. New tributaries of the Maas developed during each westward shift and incision phase of the river, which then formed their own valleys in the terrace landscape, each with its own series of side valleys formed by smaller rivulets. The dry valleys show great variation in size and morphology. Usually, a dry valley system has a dendritical structure, the largest dry valleys connecting up to a valley through which water flows all the year round.

Because of the large number of stream valleys and dry valleys the landscape is greatly dissected, particularly the higher terraces. Figure 11 gives a three-dimensional drawing of dry valleys formed in a Higher Terrace plateau (Sint Geertruid deposits) southeast of Maastricht. As accidented as it is, the landscape today is a smoothed version of the Pleistocene landscape contours prior to loess deposition, the anthropogenetic erosion and the formation of colluvial accumulations, which are over 5 m thick in many places (Kuyl 1980).

Finally, the extensive Cretaceous and Tertiary chalk beds

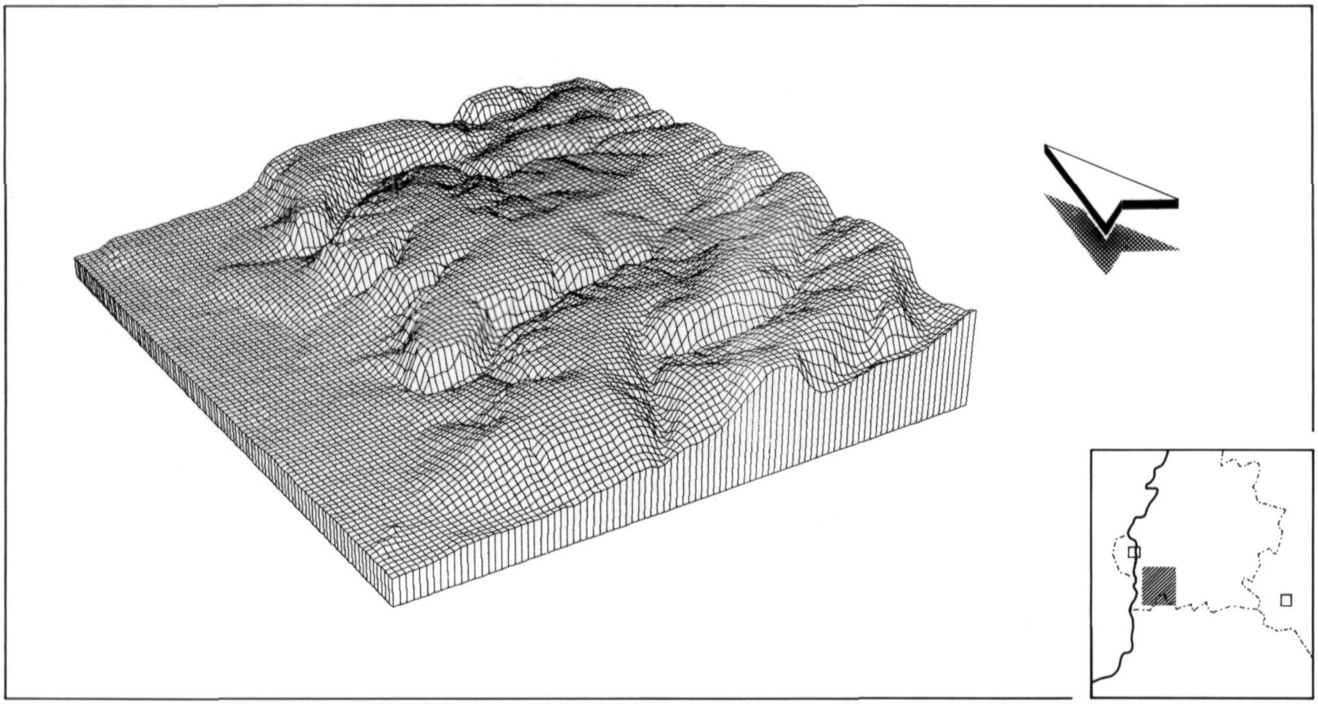

Fig. 11. Three-dimensional view of dry valleys formed in a higher (St.Geertruid) terrace plateau southeast of Maastricht. x between 178000 and 184500, y between 308200 and 315500 in the topographical map system. Vertical scale magnified 8x. Drawing made by -and published with the courtesy of- Dr J. Hartman, Amsterdam.

beneath the Quaternary sediments are responsible for many karstic phenomena throughout the working area (Kuyl 1980).

2.3 The Middle and Late Pleistocene deposits at Maastricht-Belvédère

2.3.1 INTRODUCTION

After the publication of the work of the Quaternary research group (Van Kolfschoten/Roebroeks 1985), important additional evidence concerning the pit's stratigraphy was obtained in fieldwork in 1985-1988. In the winter of 1985 an east-west section running 300 m through the pit became available for study. In 1985 and 1986 K. Groenendijk and J.P. de Warrimont recorded large parts of this exposure, the largest exposed at Belvédère since 1980. In the summers of 1986, 1987 and 1988 other long sections in the western part of the pit were recorded by students of the Institute of Earth Sciences (Free University of Amsterdam), under the supervision of J. Vandenberghe. The 1985-1988 exposures were sampled for grain-size analysis by J. Vandenberghe (Amsterdam) and for soil micromorphological analysis by H.J. Mücher (Amsterdam). Faunal remains were collected by K. Groenendijk, J.P. de Warrimont and T. van Kolfschoten (Utrecht) and T. Meijer (Haarlem). The new data obtained in the 1985-1988 fieldwork have led to a modification of the stratigraphical model developed by Vandenberghe *et al.* (1985) and to a re-evaluation of the stratigraphical position of some archaeological sites already reviewed by Roebroeks (1985). The 1985-1988 fieldwork data will be published in detail elsewhere.

The framework established in this section will be used and further developed in the presentation of the archaeological sites.

2.3.2 LITHOLOGY AND LITHOSTRATIGRAPHY

When the 1985 volume on the Belvédère project was published (Van Kolfschoten/Roebroeks 1985), units 1 to 7 as published by Vandenberghe *et al.* (1985) were explicitely understood to be *lithological* units. Since then, however, three years of quite intensive geological fieldwork have shown that matters are much more complex than was initially thought, and in fact we have been using and discarding quite a series of geological models since that published in 1985 (Vandenberghe *et al.* 1985). In essence, what has been observed in recent years in the long sections available for study is that there are many lateral transitions between lithological units, which means that, for instance, lithological unit 4 develops laterally into unit 5.1. Therefore a strict separation of lithological and lithostratigraphical units has to be made in the geological nomenclature used. The research group working at Belvédère agreed to designate the

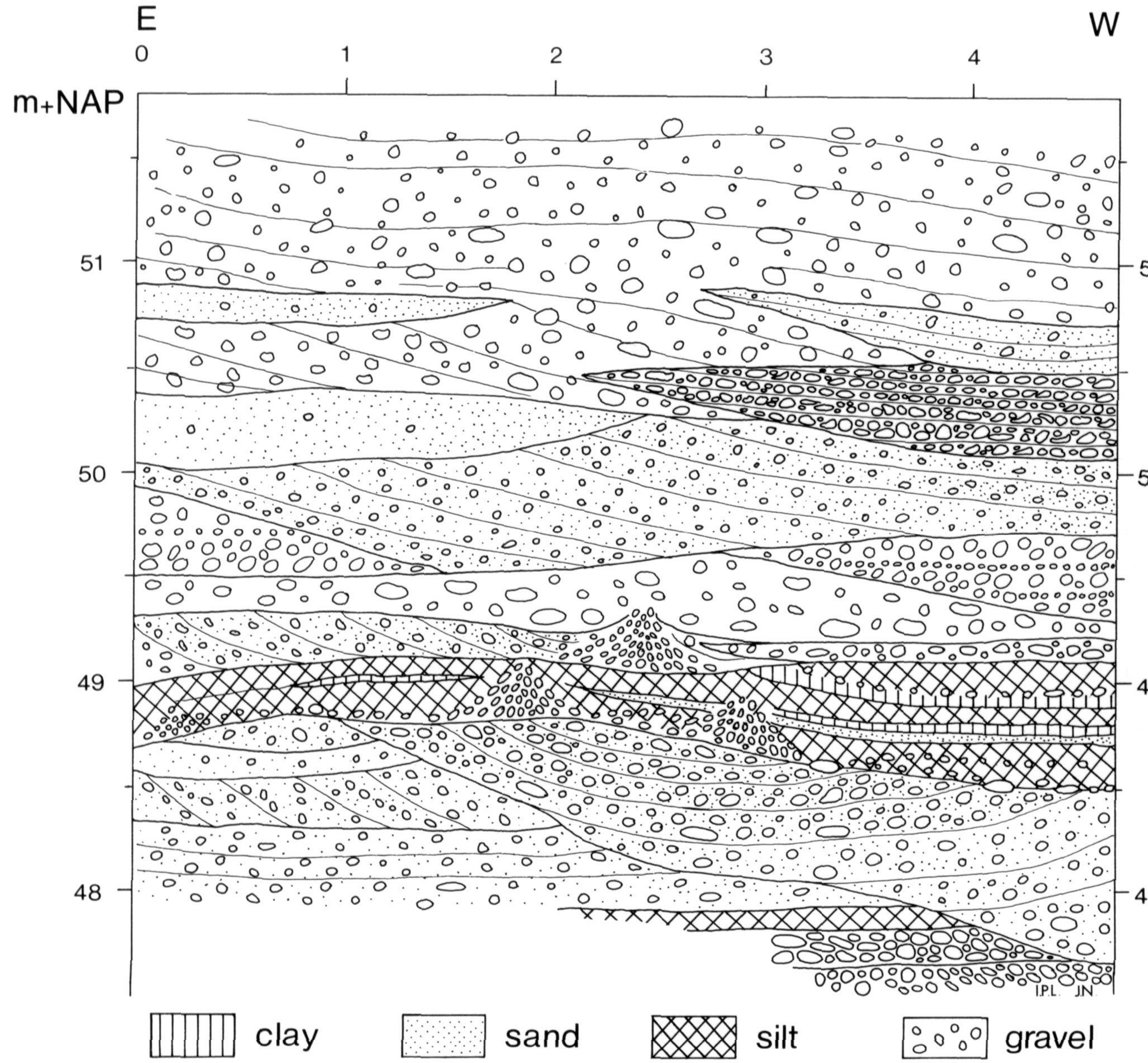

Fig. 12. Representative vertical section through the terrace gravel of Unit 3 (III-A) (from Vandenberghe *et al.* 1985).

lithological units in the same way as originally published (Units 1 to 7, cf. Vandenberghe *et al.* 1985), and to award Roman figures to the *lithostratigraphical* units. So, basically, we are dealing with two systems: lithology (Units 1 to 7) and lithostratigraphy (Units I to VII).

2.3.2.1 Lithology

Units 1 and 2 Most of the Pleistocene sediments in the Belvédère pit were deposited on the Palaeocene chalk subsoil (Unit 1) belonging to the Houthem Formation (Kuyl 1971). Oligocene marine sands (Unit 2) are found on top of the chalk in some places. The base of the Pleistocene deposits at Belvédère has an irregular surface due to karst formation and/or erosion, its average elevation being 45 to 47 m above NAP (Klein 1914; Brueren 1945; Bosch 1975).

Unit 3 Unit 3, above Units 1 and 2, consists of gravel and has a maximum thickness of 7 m. A representative vertical section of this unit is shown in figure 12. Unit 3 is heterogeneous in texture and structure: there are a number of alternating beds and lenses of different sizes and contents, but trough and narrow tabular crossbeddings are dominant.

Cobbles of several dm do occur but, on the whole, the pebble diameter is a few cm. Lenses of fine to coarse, gravelly sand occur, while occasionally silts and clays were deposited in depressions, at the base of which a gravel horizon is found. On the basis of the sedimentary characteristics observed, Vandenberghe *et al.* (1985) conclude that this lithological unit was deposited by a river with multiple channels, the individual channels not having existed for a long time. The unit was most likely formed by a braided river system.

Unit 4 Unit 4, described in the Vandenberghe *et al.* (1985) paper as consisting of greyish-white to light greenish sand with intercalated pebble horizons and being of fluvial origin, was subdivided after the 1985-1988 fieldwork. In 1985 attention was already drawn to the lateral transitions which led Vandenberghe *et al.* (1985) to distinguish several facies in this unit. At the time at which these sentences were written (February 1988), the following subdivisions had been made within lithological Unit 4:

- Unit 4.1: finely laminated fine sands and clays with the odd layer of gravel; maximum thickness about 2 m,
- Unit 4.2: a mainly horizontally bedded alternation of gravel layers, silty sands and sandy silts; maximum thickness about 2 m,
- Unit 4.3: predominantly laminated fine sands with a few clay bands, calcareous in parts; up to 1.5 m thick. Especially at its base it contains obliquely bedded coarser sands and gravel layers,
- Unit 4.4: a layer of up to 1 m thick consisting of greyish-yellow to greyish-olive fine sands with intercalated gravel layers. These sands, which are calcareous in parts, were observed in a number of fining upward sequences,
- Unit 4.5: fine sands, greyish olive silty clays, calcareous tufas (up to 90% $CaCO_3$) and intercalated sand layers. It is possible to make the following divisions within this subunit. Unit 4.5.1 consists of a lateral sequence of greyish olive silty sands and silty clays of up to 1 m thick, here and there overlain by Unit 4.5.2, consisting of calcareous tufas (up to 90% $CaCO_3$) and having a maximum thickness of 0.8 m, overlain by greyish-olive clays. Unit 4.5.3 consists mainly of silty clays and has a recorded thickness of up to 0.5 m.

Unit 5 Unit 5 consists of yellowish-brown to reddish yellow sediments that become finer in grain size from the base (Unit 5.1) to the top (Unit 5.2) and have a maximum thickness of about 2 m.

- Unit 5.1, which is everywhere stratigraphically present beneath Unit 5.2, consists of a true mixture of sand and silt loam, showing a characteristic bimodal grain-size distribution with peaks at 80-115 μm and 30-38 μm.
- Unit 5.2. consists of a better-sorted silt loam with a small amount of admixtured sand, which decreases towards the top of the sub-unit (Vandenberghe *et al.* 1985; see also fig. 13 in this volume).

The boundary between the two subunits was not always clear in the field, but in places it is very well marked by an erosional layer containing pebbles and cobbles.
Likewise, it was not always possible to differentiate between sediments of Unit 4 and Unit 5.1, which in many places show both a gradual lateral and a gradual vertical transition. Brownification, clay enrichment and homogenization as a result of soil formation disturb the original sedimentary structures in many places and have changed the textural properties of both Unit 4 and Unit 5.

It is furthermore worth mentioning that in the field Unit 5.2 showed a striking resemblance to Saalian loess deposits exposed in other pits in the region. Mücher (1985), however, explicitly interpreted this unit not as a 'pure loess', but as a sediment consisting of fluviatile deposits mixed with loess that was displaced slightly after its original deposition by wind and possibly also with loess that was deposited directly by the wind.

Unit 6 Unit 6 consists of silts and silty loam, is up to 3 m thick and has been divided by Vandenberghe *et al.* (1985) into four subunits, 6.1 to 6.4, 6.1 being the lowermost unit in stratigraphical terms and 6.4 the uppermost unit.

- Unit 6.1 was only observed in places; it consists of a silty loam of a light grey colour (6.1.1) with a homogeneous black 'humic' horizon top (6.1.2), a sequence which has been interpreted as a steppe soil (Vandenberghe *et al.* 1985; this volume, chapter 7). It has to be stressed here that a thin layer of small stones measuring less than 1 cm was observed in most places at the boundary between the light-greyish (6.1.1) and the darker loess (6.1.2) on top of it. Likewise, in several places in the pit an erosional level was observed on top of the darker loessic sediments of Unit 6.1.
- Unit 6.1 was eroded during the deposition of Unit 6.2, which consists of redeposited sediments, partly derived from Unit 6.1 deposits. Unit 6.2 is mainly a pebble zone.
- Unit 6.3 consists of finely laminated silty loams, which almost everywhere are covered by the greyish-yellow silts of Unit 6.4.
- Unit 6.5, not presented in the Vandenberghe *et al.* (1985) paper, consists of laminated silts with intercalated sand layers, the basal part of which consists mainly of a coarsely grained reddish sandy silt, deposited after a major erosional phase.

Unit 7 The uppermost Unit 7 is a massive, yellowish-brown silty loam with a carbonate content of about 15% and a thickness of up to 6 m. The upper part had been affected by Holocene soil formation, which had caused decalcification to a depth of about 3 m.

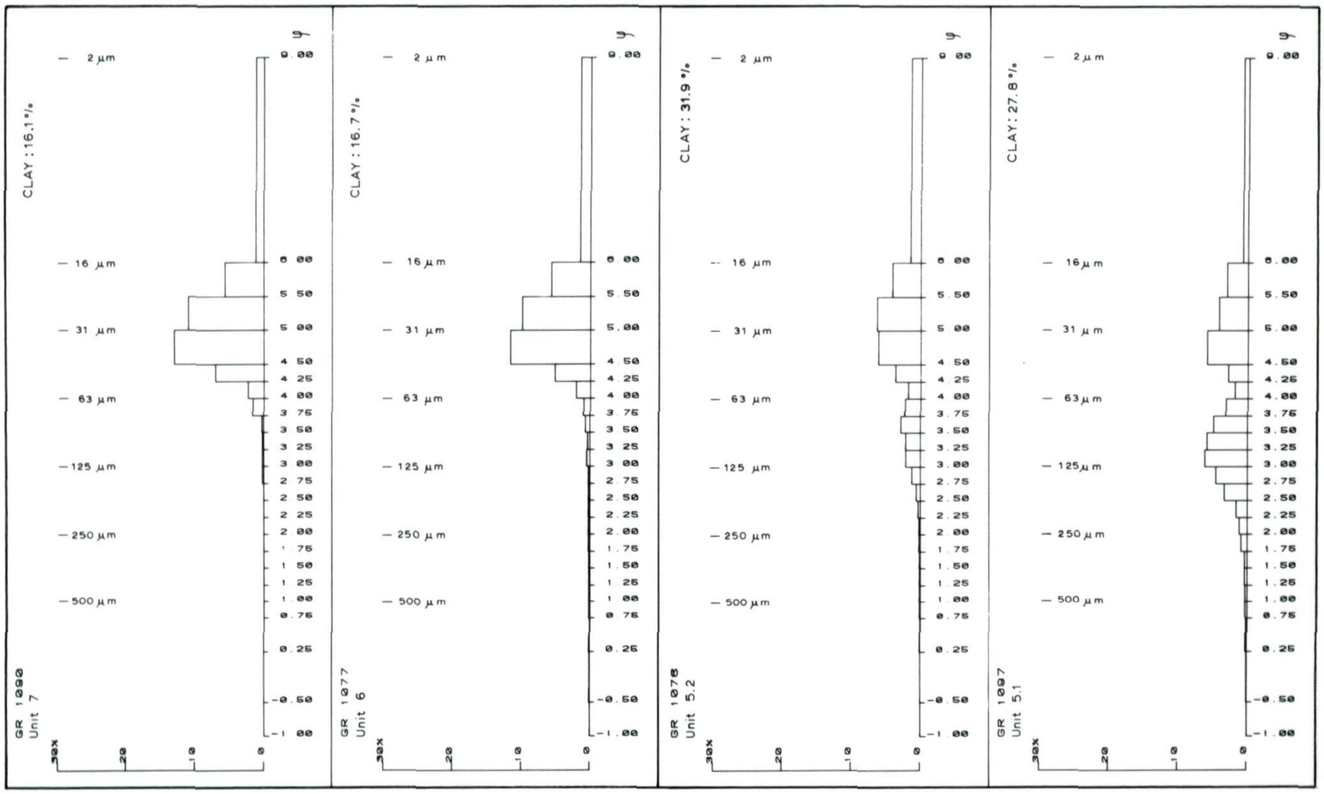

Fig. 13. Comparison of typical histograms of the grain size distribution in Units 5.1, 5.2, 6 and 7 (from Vandenberghe *et al.* 1985).

2.3.2.2 Lithostratigraphy

Figure 14 gives a very schematic representation of the stratigraphical position of the lithological units described above, as recorded in the 1987 fieldwork of the Institute of Earth Sciences. The lateral transitions which have been observed between lithological units are indicated in this figure too, as well as in table 3. This table also gives a translation of the data in terms of lithostratigraphical units.

As for the Unit IV-C complex, which is a very relevant complex from an archaeological point of view, discriminating between the smaller subunits (IV-C-I, IV-C-II and IV-C-III) is facilitated by the occurrence of erosional features between these subunits, which are (in many places) separated from each other by mostly thin (up to 5 cm thick) sand layers with small stones (most measuring less than 2 cm).

2.3.3 PALAEOSOLS

The lithostratigraphical Units IV and V and the basal part of Unit VI have been analysed micromorphologically by means of thin sections (5 to 8 cm, occasionally 8 to 15 cm). The research was carried out by H.J. Mücher, University of Amsterdam (Mücher 1985).

From the beginning of the research at the Belvédère pit onwards, micromorphological analysis was considered the most important tool for identifying the processes by which sediments containing archaeological material were deposited and for identifying and analysing post-depositional processes, e.g. soil formation.

In fact, it was thought that palaeosols could only be identified by means of micromorphological analysis or by demonstrating a catenary relationship. Other laboratory methods (e.g. granulometrical analysis) cannot provide proof of clay-illuviation processes or other forms of pedogenesis (McKeague *et al.* 1978; Mücher/Morozova 1983).

In his analysis of the Belvédère deposits, Mücher used the K-cycle concept proposed by Butler (1959) and explained in Mücher and Morozova (1983). Butler's K-cycle concept (K from the Greek *Kronos*=time) divides the Quaternary into stable periods, dominated by soil formation, and unstable periods, dominated by erosion, sedimentation, and the formation of slope deposits.

From a sedimentary point of view, two types of environments can be distinguished in sedimentary processes, namely sediment-producing and sediment-receiving areas, both of which show characteristic developments during stable and unstable phases. Figure 16 (after: Mücher 1985) gives a schematic view of the different developments that took place in these phases in the two different environments. Of course a simple correlation glacial or stadial

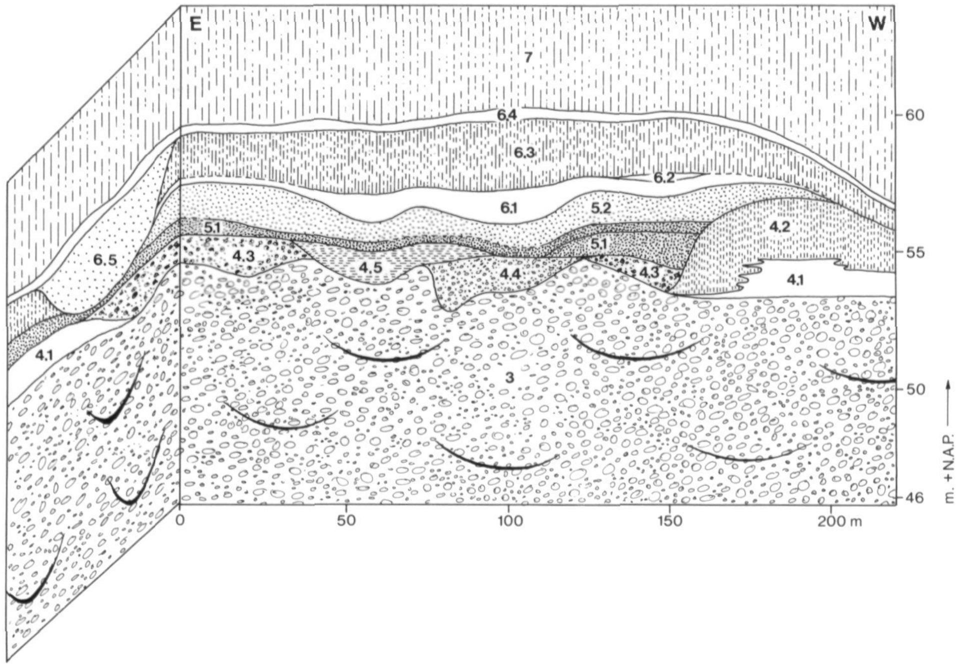

Fig. 14. Schematic cross-section through the Belvédère pit, based on the 1987 fieldwork of the Institute of Earth Sciences, Free University, Amsterdam, showing the stratigraphical position of the lithological units. Vertical scale magnified 12x.

Fig. 15. Photo of the southern part of the pit, taken in the summer of 1987, showing Units III to VII. The large boulders in the front left come from the Unit 3 gravels. The 'white band' visible halfway up the section consists of the Unit IV-C-II calcareous tufas (from a colour slide by the author).

period = unstable, and interglacial or interstadial period = stable may not be assumed. Even short-term and local events may produce slope deposits, which may bury palaeosols in areas receiving sediment, which, in turn, may be influenced by pedogenesis.

Relating the K-cycles established by Mücher to chronostratigraphical schemes is, therefore, a purely speculative matter. The concept of K-cycles is applied here to deduce local, small-scale events.

The micromorphological study of Units IV and V revealed that the 'Belvédère-pit' region may be regarded mainly as a sediment-receiving area, with sedimentation during *unstable* periods (*Ku-cycles*) and formation of palaeosols during *stable* periods (*Ks-cycles*). Mücher initially identified three Ku-cycles, during which Units IV (K_1u), V-A (K_2u) and V-B (K_3u) were formed. The stable periods following the Ku-cycles (K_1s, K_2s, K_3s) were thought to be represented by strongly to moderately truncated palaeosols, characterized by clay illuviation. Mücher interpreted these as remnants of heavily truncated luvisol palaeosols. In the absence of an A horizon and also the main part of the B horizon such a classification can only be tentative (Mücher 1985). Luvisols[1] are generally formed under deciduous forests in a temperate climate. The problems associated with differentiating between Unit 4 and Unit 5.1 sediments and interpreting lithological differences in lithostratigraphical terms are, of course, also encountered in interpreting the palaeosols. Lithological identification of the parent material -and subsequent lithostratigraphical interpretation- was occasionally problematic.

As already stated earlier in this chapter, new interpretations of the geology of the pit were generated in the 1985-1988 fieldwork, and older models have been discarded. These new models will be published in detail in due time, and in this volume only the most simple option will be presented. As for the interpretation of the palaeosol remnants present in the Unit IV-Unit V complex, the new data indicate that only two periods of major soil formation are observable in the Unit IV-V sequence. It now seems that the traces of soil formation found in the Unit IV and V-A deposits in fact all date from one major stable period. Future fieldwork and laboratory analysis will focus on this problem, which will therefore not be detailed here. Referring to the 1985 paper by Mücher, we can say that traces of this first palaeosol have been found in sections Mi_2 (thin sections 749-753), Mi_3 (thin section 839), Mi_6 (thin section 903-904) and at Site F (thin sections 0.440, 0.452, Mücher, pers.comm., 1987).

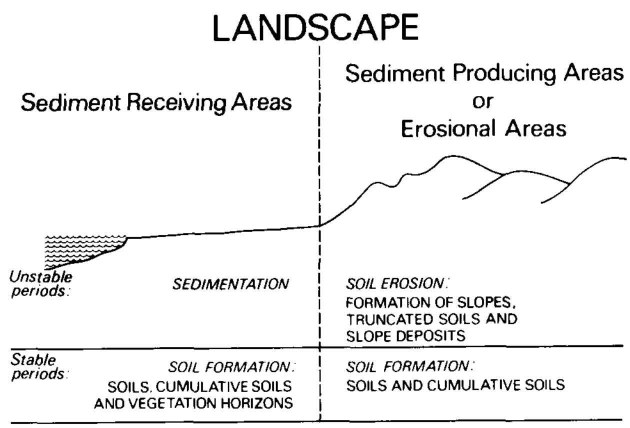

Fig. 16. Schematic representation of the events that take place in the landscape during stable and unstable periods (from Mücher 1985).

Table 3: Stratigraphical survey of the lithological units presented above (left) and their relation to the lithostratigraphical units (right).

LITHOLOGY			LITHOSTRATIGRAPHY	
7			VII	
	6.4			VI-E
	6.5			VI-D
6	6.3		VI	VI-C
	6.2			VI-B
	6.1			VI-A
	5.2			V-B
5			V	
	5.1			V-A
	3	5.1		III
	4.5.2			IV-C II
	1			I
4	4.4	5.1	IV	IV-B
	4.3	5.1		IV-A
	4.1/4.2			III-B
			III	
3				III-A
2			II	
1			I	

In the unstable cycle following the formation of the luvisol in the top part of the Unit IV/V-A complex the soil was eroded and Unit V-B was deposited. Subsequent soil formation resulted in a well-drained luvisol, as is clearly observable in sections Mi_2 and Mi_4 (Mücher 1985). On the basis of its stratigraphical position and its morphology, the soil formation in this stable cycle is correlated with the 'Eemian' Sol de Rocourt (Gullentops 1954).

Units VI and VII have yet to be subjected to systematical micromorphological research. However, the black 'humic' horizon in the top part of Unit VI-A has been interpreted by Vandenberghe *et al.* (1985) as a 'steppe soil' in view of a suggested catenary relationship between the topographical position and hydromorphic properties of this 'soil' (but see chapter 7). The upper part of Unit VI (i.e. VI-E) contains a cryoturbated horizon, which strongly resembles the Nagelbeek Horizon (Haesaerts *et al.* 1981), with which it is correlated on the basis of its characteristics and lithostratigraphical position. The Eltville tuff layer which so distinctly marks this horizon (Meijs *et al.* 1983) is, however, absent here.

In several parts of the pit a second *Nassboden* was observed about 1 m above the 'Nagelbeek Horizon', i.e. in the Unit VII loess deposits (fig. 17). This '*Nassboden*' consists of a dull, light-yellow (2.5 Y 6.5/3) 25-cm thick band contrasting well with the bright yellowish calcareous loess (10 YR 6.5/6) surrounding it. The upper part of the *Nassboden* consists of a 'rusty' layer, of a brown (7.5 YR 5/8) colour.

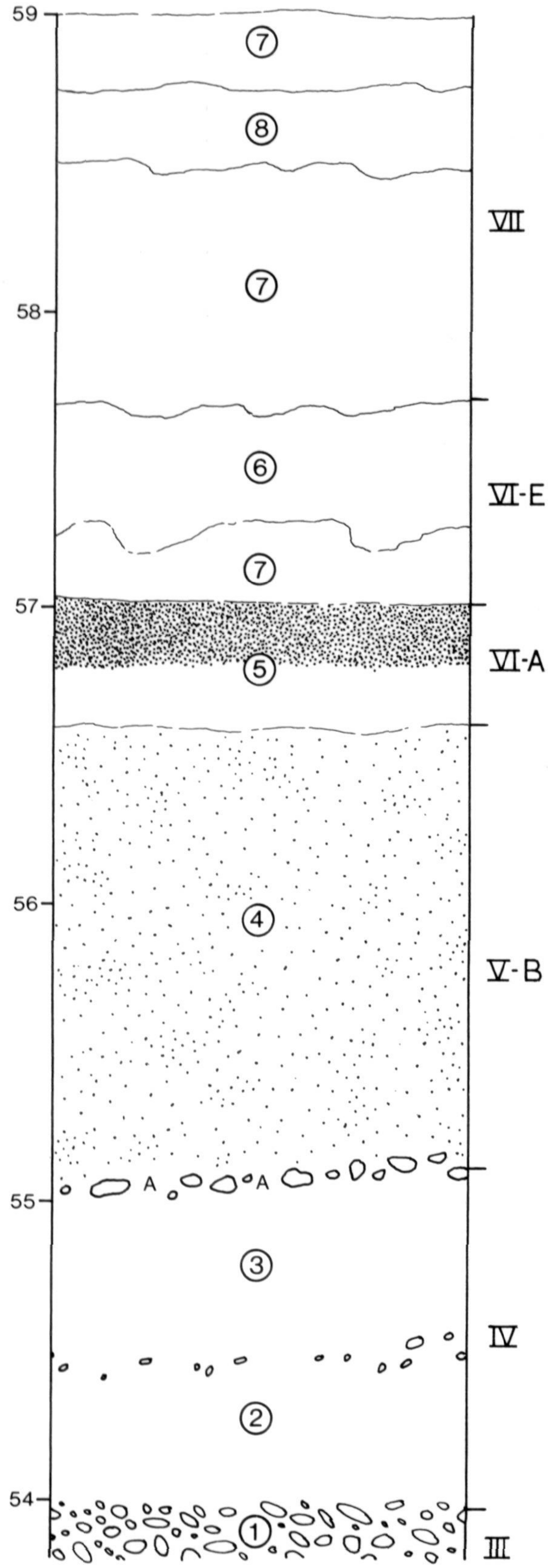

Fig. 17. Section recorded in 1983 showing the presence of a '*Nassboden*' (8) above the Horizon of Nagelbeek (approximate coordinates: 175270/319870).
1 the top of the Unit III terrace gravels
2 loamy fine sand (2.5 Y 5/3) – Unit IV
3 sandy loam (2.5 Y 5/3 – 7.5-10 YR 4/6) – Unit IV-C
4 silt loam (7.5 Y 5/6) – Unit V-B; at its base a gravel layer containing artefacts (A) and stones of up to 30 cm
5 Unit VI-A silt loam complex
6 Nagelbeek Horizont
7 silt loam (10 YR 6.5/6), calcareous
8 silt loam (2.5 Y 6.5/3) with a bright brown (7.5 YR 5/8) upper part

2.3.4 CLIMATIC AND PALAEOENVIRONMENTAL INDICATORS

Unit III According to Van Kolfschoten (1985), remains of *Elephas antiquus* had in the past been found *at the base* of the Unit III gravels. The records of other northwestern European sites that have yielded remains of *Elephas antiquus* show that this species is generally associated with temperate forests. In 1985 J.P. de Warrimont found a loamy layer with leaf impressions and molluscs in the middle of Unit 3. According to Meijer (1985, pers.comm., 1986), the molluscs indicate a continental temperate climate. Moreover, there are very few subarctic elements in the molluscan fauna.

In recent years, several remains of *Mammuthus primigenius*, *Coelodonta antiquitatis*, *Equus* sp. and *Cervus elaphus* have been found in the upper 2 m of Unit III-A (fig. 18). In 1986, Groenendijk and De Warrimont discovered a number of small mammal remains in the top part of Unit III-A, which included remains of the Norwegian lemming (*Lemmus lemmus*), ground squirrel (*Spermophilus* cf. *undulatus*) and the short-tailed vole (*Microtus arvalis*) (Van Kolfschoten *in press*). This faunal assemblage indicates that the upper part of Unit III-A must have been formed in a tundra-steppe environment, under cool climatic conditions. In the upper part of the Unit III-A gravels a series of large involutions were observed, testifying to at least local permafrost conditions. The same phenomenon has been observed in a nearby exposure (Klinkers quarry) (Vandenberghe *et al.* 1985).

Unit IV According to the palaeontological data, a distinct climatic change took place during the deposition of the fluviatile Unit IV. The mammalian as well as the nonmammalian faunas indicate that the basal part of this unit was deposited under *continental* warm-temperate conditions, while the upper part of the unit (IV-C) was clearly deposited during a *humid* warm-temperate phase (Van Kolfschoten 1985; Meijer 1985). A detailed environmental reconstruction of the archaeological sites situated in the Unit IV deposits will be given in chapter 8.

Fig. 18a. Mammoth tusk in the top part of the Unit 3 gravels, 1986 (from a colour slide by J.Vandenberghe).

Fig. 18b. *Mammuthus primigenius* molar from the Unit 3 gravels: buccal view of M2sin (BP1) (after: Van Kolfschoten 1985).

Unit V-A The very gradual (lithological) transition from Unit IV-C-III sediments to the overlying Unit V-A deposits suggests that the formation periods of these two units were closely related in time, and that they were very probably formed under the same climatic conditions. The formation of Unit V-A was followed by a major period of soil formation under warm-temperate climatic conditions.

Unit V-B This unit is considered to be a cold-phase deposit that consists of loess which was displaced after its original deposition by the wind. The palaeosol on top of Unit V-B is interpreted as having been formed under deciduous forest vegetation during the Eemian interglacial.

Unit VI This unit was, for the most part, formed under cold humid climatic conditions. The lower part of Unit VI (Unit VI-A, VI-B) has been affected by regularly developed involutions, reaching a constant depth of 70-120 cm. They have been interpreted as cryoturbations and, on the basis of their size and widespread occurrence, as indications of the existence of a former permafrost, which, according to Vandenberghe *et al.* (1985), most probably dates from the Weichselian Lower Pleniglacial. A cryoturbation level was also observed in the top part of Unit VI, which is datable to the period of permafrost conditions in the Weichselian Upper Pleniglacial.

Unit VII This is a typical loess deposit of the Weichselian Pleniglacial, in the upper part of which a Holocene Luvisol has developed.

2.3.5 DATING EVIDENCE

In this section a short survey will be given of the data relevant to the relative and 'absolute' dating of the different units in the Maastricht-Belvédère pit. More details are found in the sections dealing with the individual units.

The presence of *Mammuthus primigenius* and *Coelodonta antiquitatis* in the upper part of Unit III-A indicates that these sediments were deposited after the Holsteinian interglacial (Van Kolfschoten 1985). Paulissen (1973) dated the Caberg Middle-Terrace deposits of Unit III-A to the Saalian in his Maas-terrace stratigraphy. He is of the opinion that the younger Middle Terrace of Eisden-Lanklaar was also formed in the Saalian period. This would imply a relatively early Saalian age for Unit III-A.

Unit IV, which also forms part of the Caberg deposits, was dated on the basis of different independent forms of evidence. The micro-mammals indicate that Unit IV was formed in a warm-temperate phase before the arrival of the Saalian glaciers in the central Netherlands (Van Kolfschoten 1985); the molluscan evidence indicates that Unit IV was formed during a warm-temperate phase of an interglacial character between the Holsteinian and the Eemian (Meijer 1985).

Thermoluminescence dating (TL) at the laboratory at Oxford of five burnt flints from Unit IV-C yielded an absolute age of 270 ±11/± 22 ka (OxTL 712k, Huxtable/Aitken 1985), while a preliminary Electron Spin Resonance (ESR)

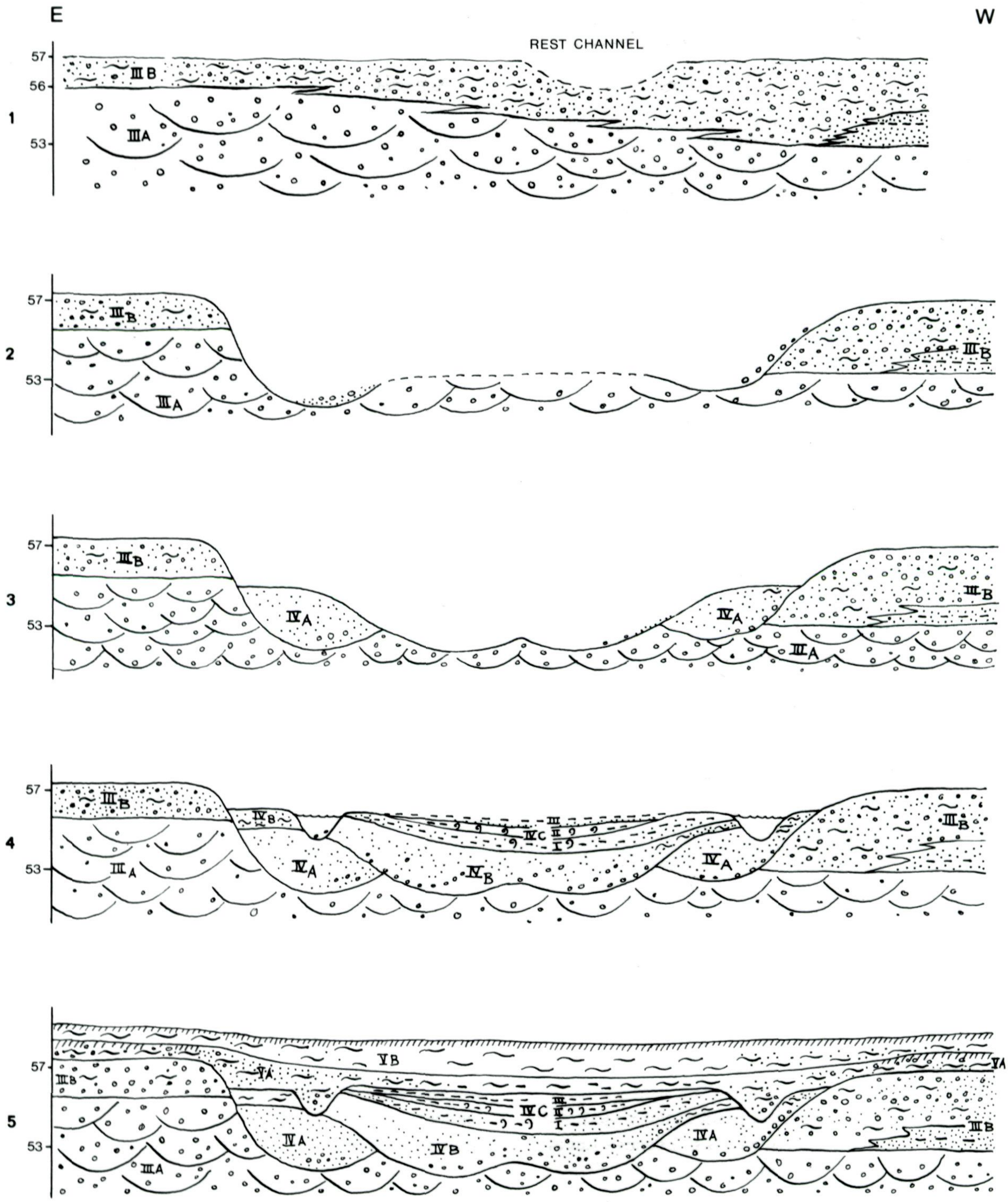

Fig. 19. Idealized representation of the genesis of the Middle Pleistocene sequence at Maastricht-Belvédère. The graphic presentation starts (1) at the end of the braided-river system, the main channel shifting its course to the east of the present Belvédère site. 5 shows the situation after the formation of the Unit V-B deposits (see table 4).

Table 4: Schematic summary of the Middle Pleistocene sequence at Maastricht-Belvédère.

lithostratigraphy		sedimentary processes/soil formation	climatic indications	archaeology	fauna[2]
		SOIL FORMATION (luvisol)	warm-temperate		
V-B		- formation of Unit 5.2 'loessic' sediments in a fining upwards sequence	cold	isolated finds	
		SOIL FORMATION (luvisol)	warm-temperate		
V-A		- alluvial deposition of a Unit 5.1 mixture of sands and loams (overbank deposits)			
IV-C	-III	- fluvial deposition of silty sands and clays (4.5.3) (overbank deposits)	warm-temperate	Sites A,D,F,H,K	isolated horse molars deer
	-II	- formation of calcareous tufas (4.5.2), up to 90% CaCo$_3$, in depressions			Fauna 4
	-I	- deposition of greyish olive sands and clays (4.5.1), filling depressions	warm-temperate ('atlantic')	Sites B,C,G	
IV-B		- formation of sandy deposits with intercalated gravel layers in gullies cut into older sediments (4.4)		isolated finds	Fauna 3
IV-A		- finely grained laminated sands deposited in abandoned branches of the main system (4.3)	warm-temperate ('continental')		
III-B		- more finely grained layers (4.1, 4.2) deposited at margins of the braided river			
III-A		- formation of gravel Unit 3 by a major braided river system	cold / partly permafrost	isolated finds	Fauna 2 Fauna 1

age determination of molluscs from Unit IV-C, carried out by R. Grün and O. Katzenberg, of Cologne, yielded an age of 220 ± 40 ka (pers.comm., 1985). Further dating of sediments, burnt flints and fossils is in progress (see section 8.3).

The heavy mineral association of the loess fraction of Unit V-B corresponds to that of pre-Weichselian loess deposits in Belgium and West Germany (Meijs 1985). A soil sample taken from the Bt horizon of the 'Rocourt' soil in the upper part of Unit V yielded TL ages of more than 75 ka (Aitken *et al.* 1986, sample 712h2).

We have already mentioned above that Units VI-A and VI-B were affected by a period of permafrost conditions in the Weichselian Lower Pleniglacial, which is dated 60-72 ka (Vandenberghe 1985b). Consequently, the sediments affected by these conditions have to be assigned an Early Weichselian age (see furthermore chapter 7).

According to Haesaerts *et al.* (1981), the Nagelbeek Horizon has an age of about 20 ka. Debenham (in: Aitken *et al.* 1986) performed a TL age determination of the layer presumed to be the Nagelbeek Horizon at Belvédère and obtained an age of 13.3 ± 3.0 ka (cf. Wintle 1987).

Overlying the Nagelbeek Horizon are the Unit VII loess deposits, which have an average TL age of 17.5 ± 3.5 ka (Huxtable/Aitken 1985; Aitken *et al.* 1986; cf. Wintle 1987).

2.3.6 STRATIGRAPHICAL AND PALAEOENVIRONMENTAL SYNTHESIS (fig. 19)

At this stage of the research only a preliminary interpretation of the sequence of events can be given. The interpretation given below, focussing solely on the Middle Pleistocene sediments, is based on partly unpublished geological field-

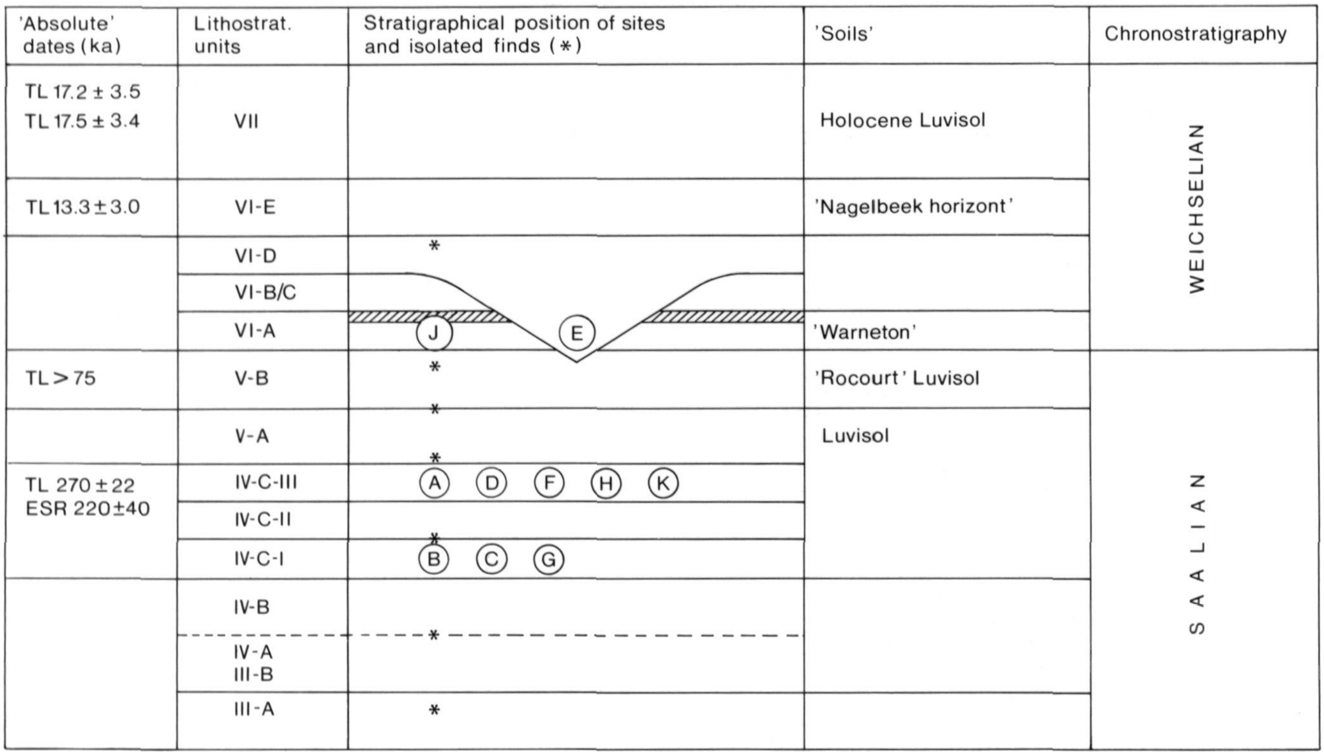

Fig. 20. Idealized survey of the stratigraphical position of the archaeological sites.

work supervised by J. Vandenberghe, who will publish the geological findings in detail elsewhere. As no further research has been done on the Weichselian sediments in the pit, the reader is referred to Vandenberghe *et al.* (1985) for details. Figure 19 gives a schematic illustration of the genesis of the Middle Pleistocene deposits in the Belvédère pit, based on a compilation of several larger sections recorded in 1981-1987.

Unit III

The gravel of Unit III-A was deposited by a major braided river system, the centre of which was situated at the site of the present Belvédère pit during the formation of the gravel unit (Unit III-A).

The more finely grained lithological Units 4.1 and 4.2 (III-B) overlying the gravels of Unit 3 may be considered marginal deposits of a (slightly) later successor of this river system, which had taken a more easterly course. By this time only a channel remained at the site of the pit. These sediments may have been deposited under climatic conditions comparable with those under which the gravels of Unit 3 were deposited. In the western and the eastern parts of the pit frost fissures have been observed in Unit 4.1.

Unit IV

– IV-A: In the following phase lithological Unit 4.3, consisting of laminated fine sand, was deposited in more localized channels, that were rather inactive and were probably deserted branches of the main system, which were slowly filled with fine sands (climbing ripples). Two probably contemporary channels were observed. They cannot be interpreted as main channels and are more likely to have been peripheral ones which contained water in times of floods.

– IV-B: The shallow channels still remaining after this phase were filled with Unit 4.4 deposits, coarser sands with intercalated gravel layers.

– IV-C: On top of these sands loamy layers with intercalated layers of sand (IV-C-I) were deposited in a calm environment, in which calcareous tufas (IV-C-II) were formed in a backswamp-like environment (lithological Unit 4.5.2). These finely grained sediments are overlain by clays and silt loams (IV-C-III).

Human occupation took place *before* the formation of the calcareous tufas,which at Sites B, C and G were present *above* the finely grained sediments which contained the archaeological remains, while a second archaeological level is placed *after* the formation of the calcareous tufa. Sites A, D, F, H and K are regarded as being situated in this upper level IV-C-III.

Unit V

– V-A: After the formation of Unit IV-C, the river disappeared from the site of the pit; the Unit V-A deposits, which are high-water sediments, here and there alternated with high-energy deposits, are interpreted as *overbank deposits* of a large river system,

The formation of Unit V-A was followed by a major stable period, as is apparent from the remnants of a luvisol palaeosol formed in the top part of the Unit IV/V-A complex.

– V-B: Elsewhere, a more local origin has been suggested for these waterlaid sediments (Vandenberghe *et al.* 1985), but heavy-mineral-analyses (Krook *unpublished*) point to a more regional provenance.

The Unit V-B sediments were the parent material in a second major period of *soil formation*, resulting in the development of a well-drained luvisol, correlated with the 'Eemian' *Sol de Rocourt* (Gullentops 1954).

Table 4 gives a schematic summary of the Middle Pleistocene sequence at Maastricht-Belvédère, while figure 20 gives an idealized schematic survey of the stratigraphical position of the archaeological sites to be presented in this volume.

notes

[1] classified in the Netherlands as *radebrik-gronden* (De Bakker/Schelling 1966) and in West Germany as *Parabraunerde* (Mückenhausen 1962).

[2] Van Kolfschoten 1985; *in press*)