The Middle and Late Pleistocene sedimentary and climatic sequence at Maastricht-Belvédère: the Type Locality of the Belvédère Interglacial

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Abstract

The Middle and Late Pleistocene sedimentary sequence at Maastricht-Belvédère shows braided-river deposits at its base, which are covered by sediments from a meandering river system that were deposited during a pre-Eemian interglacial. In turn these sediments are covered by loamy deposits. The Luvisol in the upper part of the loamy sediments has been interpreted as the Eemian/Rocourt soil, which separates the Saalian deposits from the overlying Weichselian deposits. The fluvial sequence shows a cyclicity that is typical of alternating temperate and periglacial environmental conditions. The fluvial development has resulted in the formation of the Caberg terrace.
Periglacial phenomena have been observed at four different levels; they represent four cold phases, two of Saalian and two of Weichselian age.
The combined palaeo-ecological evidence of the mollusc- and vertebrate fauna from the upper part of the fluvial deposits indicates interglacial conditions and a (partly) wooded environment during the warm phase which has been called the Belvédère Interglacial. Human occupation mainly took place during the climatic optimum of the Belvédère Interglacial. The middle palaeolithic industry with its Levallois recurrent technique is amongst the earliest middle palaeolithic ones in Northern Europe.
The stratigraphical position of the Belvédère Interglacial is discussed. The mammalian faunas from the Pleistocene sequence and the geological evidence indicate an intra Saalian age. A correlation of the Belvédère Interglacial with the Hoogeveen Interstadial remains uncertain and problematic. The radiometric dates of burnt flints give an age of 250 ± 20 ka for the Belvédère Interglacial which indicates a correlation with stage 7 of the Oxygen Isotope record. This correlation seems to provide 'the best fit' at the moment despite the discrepancies discussed.

Introduction

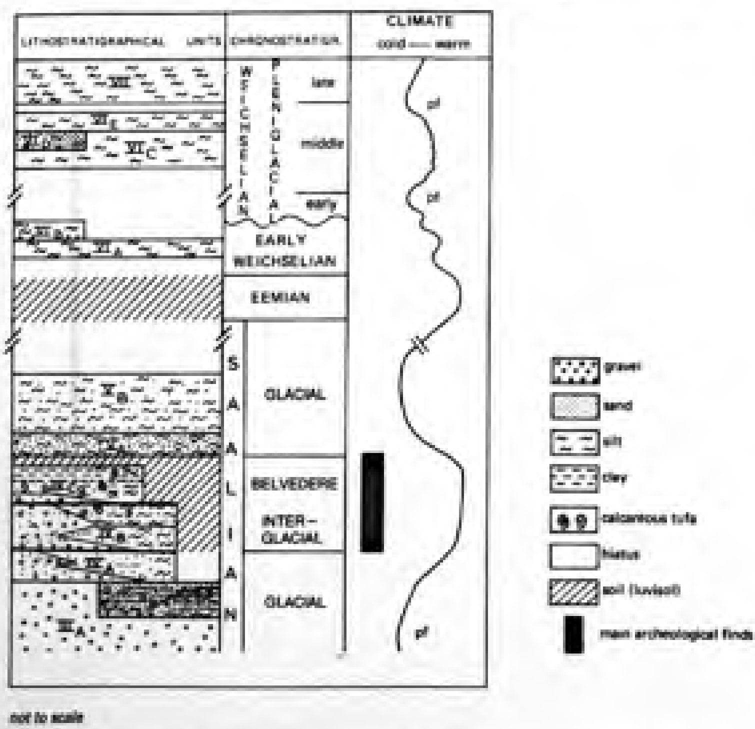
The purpose of this paper is to give a concluding review of the Pleistocene sedimentary sequence at Maastricht-Belvédère and to discuss the stratigraphical position and the character of the intra-Saalian warm temperate 'Belvédère Interglacial' phase (Vandenberghe, 1988a).

The Middle and Late Pleistocene sequence

Stratigraphy and age

The results published in this volume are, in general, in close agreement with those discussed in earlier papers (e.g. van Kolfschoten & Roebroeks, 1985; Vandenberghe et al., 1987). In detail, however, they are much more refined. The different lithological units (Figure 1) have been incorporated into a lithostratigraphic framework (Figure 2).

Figure 1
Photograph of the southern part of the pit showing Units III to VII. The photograph was taken in the summer of 1987. The large boulders at the front left are from the gravels of Unit III. The white band visible half way up the profile consists of calcareous tufas in the interglacial deposits of Unit IV.



not to scale

Figure 2
Lithostratigraphical succession of the Middle and Late Pleistocene sequence at Belvédère, paleoclimatic reconstruction and situation of the main archeological findlevels.

Lithostratigraphic Unit III contains the gravelly sediments deposited by a braided river. Lithostratigraphic Unit IV consists of sandy sediments deposited by a meandering river. A threefold subdivision can be made according to the three consecutive stages of meander development (IV A-B-C). Each of these stages contains channel bed deposits, finer channel infill deposits and loamy overbank deposits. The sequence ends with the accumulation of an overall clayey deposit (IV Cβ). Lithostratigraphic Unit V comprises a loamy cover on top of Unit IV. A Luvisol separates Unit V from the overlying lithostratigraphic Units VI and VII.

The gravel Subunit III A contains faunal remains which point to a post-Holsteinian age (van Kolfschoten, 1985). Subunits IV B-C clearly represent full interglacial conditions as shown by their mollusc and mammal fauna and soils (Meijer, 1985; Duistermaat, 1993; van Kolfschoten, 1985, 1990; Huijzer & Mücher, 1993). Thermoluminescence datings on burnt flints from the archaeological sites in Subunits IV B-C resulted in a TL age of 250 ± 20 ka (Huxtable, 1993). This intra-Saalian interglacial has been called the "Belvédère Interglacial" (Vandenberghe, 1988a). An extensive discussion of its stratigraphical position is given below. The well-developed Luvisol (Mücher, 1985) on top of Unit V has always been interpreted as the Rocourt soil (Gullentops, 1954) which dates from the last interglacial (Paulissen, 1973; Vandenberghe et al., 1985). The character of the Rocourt soil (Mücher, pers. comm.) excludes a correlation with the somewhat less developed Early Glacial soils recognized in the Belgian loess belt (Haesaerts & van Vliet-Lanoë, 1981). Traces of polycyclic development of the soil have not been found. To assign an older (intra-Saalian) age to the soil on top of Unit V (in Belvédère) might theoretically be possible but there are no sound indications for a large hiatus between the top of Unit V and the directly overlying Weichselian sediments. Because of their position between the Holocene soil and the Rocourt soil, Units VI and VII are attributed to the Weichselian (Figure 2). According to TL analyses (Debenham, 1993) the Nagelbeek horizon (top of Unit VI) as well as the overlying Unit VII are of Late Pleniglacial age. Some radiocarbon dates from shells in nearby exposures, assign the underlying Subunit VI D to the beginning of the Late Pleniglacial and Subunit VI C to the Middle Pleniglacial (Vreeken, 1984; Huijzer, 1991). Subunits VI A-B are of Weichselian Early Glacial or Lower Pleniglacial Age (see below). The homogeneous loess (Unit VII) corresponds with the Brabantian loess, while the finely laminated loess of Subunit VI C is a typical example of the Hesbayen loess (Gullentops, 1954).

Periglacial processes and environment

Saalian (predating the Belvédère Interglacial: Unit III and Subunit IV A)

Although periglacial phenomena from the first cold period were not abundant, they are nevertheless significant. Within Unit III, a braided river deposit, local involutions in fine-grained layers as well as small isolated disturbances with pebbles in upright positions are found within the gravel beds. Nearer the top of the same unit, when sedimentation had decreased, more extensive, flat-bottomed involutions occur. Taking into account the otherwise very permeable nature of the gravel unit it is likely that frost action produced these deformations (Vandenberghe, 1988b). The relatively large amplitude of the involutions at the top of the unit points to permafrost conditions. The gravel layer (Unit 3.1) contains remains of Mammuthus primigenius and Coelodonta antiquitatis which are known to prefer a cold climate and open areas. The braided-river characteristics of peak discharges and the high sediment load correspond with the presence of a permanently frozen subsoil which was only weakly protected by a vegetation cover and induced a low soil permeability and a large supply of sediment to the river. The end phase of braided river deposition (Subunit III B) also marks the decline in glacial conditions since only indications for strong seasonal frost activity are found (narrow frost fissures).

Severe winter conditions continued to prevail during the deposition of Subunit IV A which is also characterized by the presence of occasional frost cracks. However, a further change in periglacial environment is obvious from the shift of a braided to a meandering river pattern. From the faunal evidence this transition corresponds with the establishment of a steppe and hence a significant increase in soil cohesion and a decrease in sediment supply to the rivers. Such ecological and geomorphological characteristics point to a continental environment with still fairly cold winters, as in the previous period, but with warm summers.

Saalian (postdating the Belvédère Interglacial; Unit V)

The sedimentary record from this period is limited (Unit V). Consequently, the periglacial phenomena are also not numerous. Isolated small-scale cryoturbations and macroscopic and microscopic frost cracks are the only periglacial structures detected so far (Huijzer & Mücher, 1993; Vandenberghe et al., 1993). A significantly increasing loess component in the otherwise waterlaid deposits from that period (Kroök, 1993) is an additional indication for periglacial conditions.

Weichselian Early Pleniglacial (Subunit VI A, VI A-B)

Narrow but deep frost cracks have been formed in the lowest deposits of Unit VI (VI A). Most conspicuous, however, are the cryoturbations at the top of Subunit VI A-B (Vandenberghe et al., 1985).

Their large amplitude (70 to 120 cm) points to a former permafrost (Vandenberghe & Van de Broek, 1982), although no ice-wedge casts have been found at this level. For the time being, this cryoturbation level, which is overlain by an erosion horizon, has lithostratigraphically been correlated with the Early Pleniglacial zone of large cryoturbations and ice-wedge casts in the nearby coversands. In turn that zone has been correlated with oxygen isotope stage 4 (Vandenberghe, 1985a).

Weichselian Late Pleniglacial (Subunit VI C - Unit VII)
At the base of the gully infilling of Subunit VI D local cryoturbations with high amplitude occur (Vandenberghe et al., 1993). The upper zone of Unit VI (Nagelbeek horizon VI E and the top of Subunits VI C-D) has been heavily cryoturbated in at least two consecutive phases (Huijzer, 1991). A network of contraction polygons is strongly distorted by the two cryoturbations. In the nearby outcrop at Nagelbeek ice-wedge casts have been found in the same lithostratigraphic position, starting from below the upper cryoturbation level (Meijs et al., 1983; Vandenberghe, 1985b). It is clear that permafrost conditions prevailed during that period which, according to the age of the Nagelbeek horizon, has to be placed at about 17-22 ka. Initial soil development has been observed: an arctic brown soil near to the top of Unit VI (Kesselt soil) and a tundra gley soil (Nagelbeek horizon) at the transition to Unit VII (Huijzer, 1991).
Within Unit VII rather shallow involutions are found which are also interpreted as cryoturbations. Besides, the deposition of this upper loess has sometimes been interrupted by the development of small polygons of narrow frost cracks (Vandenberghe et al., 1985; Huijzer, 1991). Heavy mineral analysis of the loess shows an almost unique long-distance transport with only little reworking from the nearby Maas river plain (Krook, 1993).
The whole period, starting with the gully incision at the base of Subunit VI D, is characterized by very cold conditions and is correlated with oxygen isotope stage 2.

Fluvial development
In the fluvial sequence a cyclicity is observed (Vandenberghe, 1993) which is typical for alternating temperate and periglacial environmental conditions. It started with the accumulation of sediments supplied by a braided river system in a barren periglacial landscape. As soon as climatic conditions became less severe and the development of a vegetation cover started, meanders were cut. In this phase continental conditions prevailed, as testified by the presence of steppe fauna under continuing periglacial conditions. The following interglacial is characterized by the stabilization of the meandering river and by a slight aggradation. Vandenberghe (1993), found that at the beginning of a new cold period the vegetation cover is maintained for some time while temperatures are already low so that a new incision can take place: the Belvédère Interglacial deposits were dissected and transformed into a terrace. Under full glacial conditions vegetation disappeared resulting in large supplies of sediment to the river and the establishment of a braided, aggrading system. Thus this cycle of alternating periglacial-temperate fluvial evolution is closed.
Towards the end of deposition by the braided river (top of Unit III) and just before the beginning of the Belvédère Interglacial, the Maas lost one of its major affluents, the Moselle, by capture near Toul. This is clearly reflected in the abrupt disappearance of the typical Vosges minerals (Krook, 1993).
The described fluvial development at Belvédère has resulted in the formation of the Caberg terrace (Figure 3). The age of the terrace as a morphological phenomenon, is not unambiguous: the top of the fluvial gravels is Saalian (pre-Belvédère) in age, the top of the fluvial sands dates from the Belvédère Interglacial, while the Maas abandoned the terrace in the beginning of the next cold period (Saalian post-Belvédère). It should be realised that during the interglacial large parts of the alluvial plain were dry so that soil formation took place and that during the next cold period the river while already incising its new bed, only occasionally flooded the former

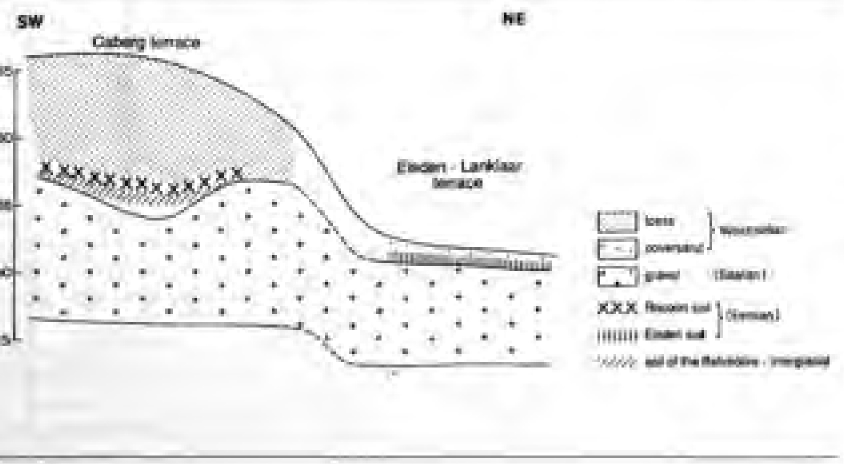


Figure 3
Simplified sequence of the middle terraces of the Maas north of Maastricht, compiled from data by Paulissen (1973) for the Eisden-Lanklaar terrace and Vandenberghe et al. (1985, 1993) and Huijzer (1991) for the Caberg terrace

river plain. It may thus be concluded that the formation of the alluvial plain, which gave rise to the formation of the terrace afterwards, came to an end during the interglacial. The sediments underlying the terrace surface date from the interglacial as well as from the preceding glacial period.

A similar evolution may be observed in the next younger terrace, the Eisden-Lanklaar terrace (Paulissen, 1973); after the incision at the beginning of the Saalian post-Belvédère period gravels were deposited (Figure 4). In contrast to the situation at Belvédère, however, no interglacial deposits are found in the Eisden-Lanklaar terrace but the gravels are overlain by aeolian sands in which the interglacial (Eemian) soil is formed (Eisden soil).

The Belvédère Interglacial

The climatic conditions during the Belvédère Interglacial.

Since no pollen has been recovered in the sections exposed in the pit, the palaeoecological and palaeoclimatological conditions during the Belvédère Interglacial have to be reconstructed mainly on the base of faunal evidence. The Subunits IV A - IV C yielded mollusc and vertebrate faunas which are indicative for the local and regional environmental conditions and the climate during deposition of these units. Subunit IV C is very rich in molluscs (Meijer, 1985; Duistermaat, 1993). A representative section through this subunit shows changes in the composition of the assemblages representing a palaeoecological development. The number of species indicative for woodland increases from 0% to 48% towards the top of the unit whereas species that inhabit areas with more open vegetation decrease from 58% to 18%. This development is interpreted as being initiated by climatic changes instead of being caused by ecological differences due to changes in the river system (Meijer, 1985).

The continuous increase of woodland species towards the top of the section shows that the later part of the Belvédère Interglacial is not represented in the section. In fact, Meijer inferred that only the first half of the warm phase is present; the second half might be represented by the Subunit IV C8 deposits and the Luvisol-type soil formation, identified by Huijzer & Mücher (1993). Soil formation was continuous during the interglacial but was occasionally interrupted by river flooding.

The climatic optimum was reached in molluscan zone D, since no new mollusc species of the most demanding group were found in the uppermost molluscan zone (E) according to Meijer (1985).

The mollusc-assemblages from Subunit IV-C are characterized by a large number of species. The fauna is diverse and differs in this aspect from Weichselian interstadial faunas from the Netherlands which have a much more monotonous composition. Species which appear in the upper part of the sequence (in the zones C, D and E according to Meijer, 1985) are absent in Weichselian interstadial faunas. Thus Subunit IV-C has been deposited under full interglacial conditions.

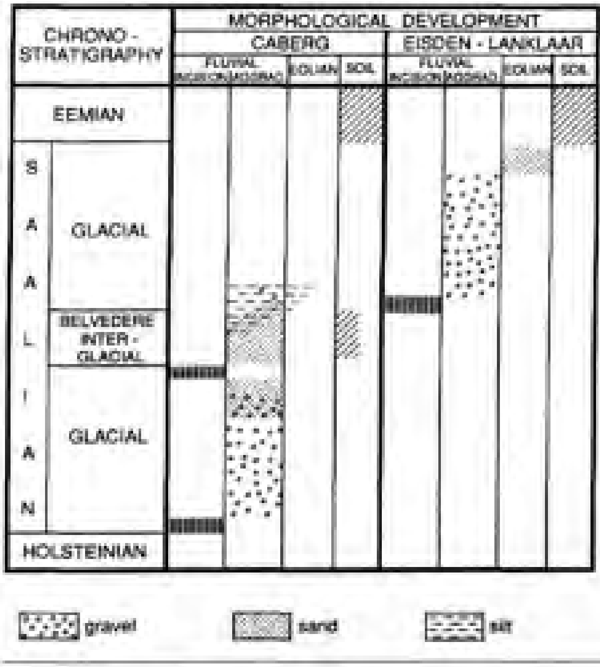


Figure 4
The morphological and sedimentological development of the Saalian Maas terraces in their chronostratigraphical and climatic framework.

The uppermost mollusc-assemblages are composed of species which, compared to the present conditions, point to a more atlantic (oceanic) type of climate (*Spermodea lamellata*, *Zonitoides excavatus* (=*Z. sepultus* in Meijer, 1985) and *Azeca goodalli*) as well as species which indicate more continental climatic conditions (*Cochlicopa nitens*, *Vallonia enniensis* and *Helicopsis striata*). A number of species (*Carychium mariae*, *Azeca goodalli*, *Vertigo moulinsiana*, *Vallonia enniensis* and *Clausilia parvula*) occur nowadays only south of the locality Maastricht-Belvédère.

Meijer (1985) also inferred absolute data on the climate during the formation of the Subunit IV-C deposits by comparison with the present habitat of the various molluscan species. He concluded that the upper part (zones D and E) had been formed during conditions characterized by high annual rainfall (at least 800 mm versus less than 700 mm at present). The mean annual temperature was at least 10°C (today 9.5-10°C). Mean July temperatures were certainly not below 15°C and probably reached 18°C (today 17.5 °C).

These conclusions are corroborated by the palaeo-environmental indications based on the vertebrate fossil record from the same unit. Most conspicuous is the occurrence of the European pond tortoise *Emys orbicularis* in sediments of Subunit IV B, IV C and IV C. The presence of this species points to a rather warm climate, necessary for the eggs to hatch. The northern limit of its actual breeding range in northwestern Europe lies south of the Netherlands (Stuart, 1982). This indicates that the mean summer temperature during the Belvédère Interglacial probably exceeded that of today. Another species indicative of interglacial conditions is the garden dormouse, *Eliomys quercinus*. Nowaday it inhabits the deciduous and mixed forests of the southern parts of western Europe up to the southern part of the Netherlands. Other species indicative for a wooded environment (the bank vole *Clethrionomys glareolus*, the wood mouse *Apodemus sylvaticus* and roe deer, *Capreolus capreolus*) are well represented in the mammal fauna from Unit IV. The occurrence of these species and the complete absence of species which prefer cold climatic conditions stress the interglacial character of the Belvédère warm-temperate phase. The tree species identified among the charcoal fragments recovered from archaeological sites in Subunit IV, C ash (*Fraxinus* sp.) and oak (*Quercus* sp.), corroborate the faunal data (Roebroeks, 1988). In summary the combined palaeoecological evidence indicates interglacial conditions and a (partly) wooded environment during the Belvédère warm-temperate phase.

Human activities in the Belvédère Interglacial

According to the studies of the molluscan assemblages uncovered during excavations at the archaeological sites C (Meijer, 1985; Roebroeks, 1988) and G (Duistermaat, 1993; Roebroeks, 1988) human occupation took place during the climatic optimum of the Belvédère Interglacial. The well preserved archaeological occurrences in the Unit IV deposits vary from highly visible 'rich' sites, with large numbers of artefacts, to background scatters where artefacts and bones occur in only very small numbers. These differences reflect the differences between places where tools were manufactured and locations where they were used in subsistence activities, e.g. the procurement of animal protein as at Site G (Roebroeks, 1988; Roebroeks et al., 1993). The middle palaeolithic industry from Maastricht-Belvédère Unit IV, with its Levallois recurrent technique (Roebroeks, 1988) is amongst the earliest middle palaeolithic ones in Northern Europe. In this area the use of Levallois technology seems to start at the beginning of the "Saalian Complex", in a simple chronological interpretation meaning Stage 8/Stage 7 of the oxygen isotope stratigraphy (see: Cahen & Michel, 1986; Tuffreau, 1987). The well established interglacial character of the human occupation at Belvédère fits well into the ecological data from the Pleistocene settlement history of northwestern Europe (cf. Roebroeks, 1988).

The stratigraphical position of the Belvédère Interglacial

The geological evidence points, as we have seen, to a pre-Eemian age for the Belvédère Interglacial period. Further dating evidence comes from the study of the faunal remains and Thermoluminescence (TL; Huxtable, 1993; Debenham, 1993) and Electron Spin Resonance (ESR; R. Grün & O. Katzenberg, pers. comm. 1989) work carried out on samples from the pit.

According to Meijer (1985) the mollusc-fauna from Unit IV indicates a late Middle Pleistocene age. A more detailed assessment is hampered by the lack of knowledge of e.g. the biostratigraphical range of some species and by the variety in facies that causes important differences in the composition of the faunas. Malacological information from Holsteinian and Eemian faunas, deposited in the Netherlands under the same conditions and during the same phase of the interglacial as the mollusc-assemblages from Unit IV, is absent (Meijer pers. comm., 1991).

Study of the mammalian faunas yielded more precise biostratigraphical indications. The mammalian fauna from the Belvédère Interglacial is rather modern in character and differs from well known Late Cromerian faunas such as Miesenheim I, Germany (Van Kolfschoten, 1990; 1991) and Westbury-sub-Mendip, Great-Britain (Bishop, 1982) in the absence of "relict" species, e.g. *Sorex (Drepanosorex) savini*, the mole *Talpa minor*, the beaver *Trogontherium cuvieri*, and *Pliomys episcopalis*. The watervole *Arvicola terrestris* and the short-tailed vole *Microtus agrestis* from the Belvédère Interglacial are more evolved than those of Cromerian age.

Holsteinian faunas are less well known. The faunal assemblage from Neede, the type locality of the Needian, the equivalent of the Holsteinian (Van der Vlerk, 1957) is small. The presence of *Trogontherium cuvieri* and a more primitive subspecies of *Arvicola terrestris* in the fauna from Neede indicate a pre-Belvédère Interglacial age. The occurrence of remains of the woolly rhinoceros *Coelodonta antiquitatis* in the gravels of Unit III at Belvédère which underly the Belvédère Interglacial deposits, corroborate the post-Holsteinian age. The woolly rhinoceros migrated from Asia to western Europe during the Early Saalian (Guérin, 1980; Van Kolfschoten, 1990). The fauna from the Belvédère Interglacial hardly differs from Eemian faunas from surrounding countries. However, a correlation between the Belvédère Interglacial and the Eemian can be excluded because of the geological position of the deposits, as shown above. These arguments lead to the conlusion that the Belvédère interglacial has an intra-Saalian age.

This statement is supported by the results of a study of a mammal assemblage from Rhenen, collected from ice-pushed sediments that were deposited before the advance of the Saalian ice-sheet (Van Kolfschoten, 1981). The Arvicola terrestris molars from the Rhenen fauna are more evolved, and therefore younger, than those from Maastricht-Belvédère Unit IV. The pre-Eemian fauna from Rhenen must therefore date from a temperate phase within the Saalian postdating the Belvédère Interglacial.

According to the analysis of burnt flints from archaeological sites in Unit IV the intra-Saalian Belvédère Interglacial has a TL age of 250 ± 20 ka (Huxtable, 1993). ESR analysis of a mollusc sample from Subunit IV C provided results consistent with the TL dating evidence, yielding a provisional ESR age of 220 ± 40 ka (R. Grün & O. Katzenberg, pers. comm. 1985; see Roebroeks, 1988). An 'absolute' terminus ante quem for the Subunit IV C deposits of 175 ± 35 ka was obtained by TL dating of a calcite concretion in the top part of that subunit (Huxtable & Aitken, 1985). These concretions were probably formed during formation of the Luvisol found in the top of Unit IV. A further terminus ante quem was provided by TL dating of the Unit V sediments, yielding an age of > 150 ka for the base of unit 5.2 (Debenham, 1993).

The results obtained by amino acid epimerization age estimates (Bates, 1993) deviate considerably from the aforementioned dates. The amino acid results point to a 'pre-Cromerian/West-Runton' age for the Belvédère Interglacial, an assessment that is irreconcilable with the stratigraphical data presented above.

The equivalent of the Hoogeveen Interstadial?

The combined dating evidence, schematically summarized in Figure 5, points to an interglacial period between the Dutch Holsteinian Interglacial and the arrival of the Saalian ice-sheet in the central Netherlands. According to the TL and the ESR dates this interglacial can be placed roughly around 250 ka.

Within the Saalian two interstadial phases have been identified by Zagwijn (1973) in pollen diagrams between Holsteinian beds and late Saalian tills (Figure 6). An earlier, relatively warm phase, called the Hoogeveen Interstadial was followed, after a short cold interval, by the somewhat cooler Bantega Interstadial. Zagwijn (1973) has argued that the Hoogeveen Interstadial could be classified as an interglacial, but he preferred to classify it as an interstadial, because it seemed to be a relatively short phase, in which *Pinus* and *Betula* were still dominant trees.

The Belvédère Interglacial has, tentatively, been correlated to the Hoogeveen Interstadial (Van Kolfschoten & Roebroeks, 1985; Vandenberghe et al., 1987; Roebroeks,

Figure 5 Schematic representation of the methods employed to date the Unit IV deposits and the results obtained.

dating method	results
1. Terrace stratigraphy	'intra-Saalian'
2. Paleosols and loess-stratigraphy	'pre-Eemian'
3. Biostratigraphy	post-Holsteinian and predating the arrival of the Saalian ice-cover
4. TL (burnt flints)	250 ± 20 ka
- terminus ante quem	
calcite	175 ± 35 ka
base unit 5.2	> 150 ka
5. ESR (molluscs)	220 ± 40 ka
6. Amino acid	'pre-Cromerian/West-Runton'

1988; Van Kolfschoten, 1990, 1993) despite the absence of palynological data at Belvédère and the lack of indications about the length of the Belvédère Interglacial. Faunal remains from the Belvédère Interglacial indicate full interglacial conditions and it remains questionable whether these conditions correspond completely with those of the Hoogeveen Interstadial as indicated by the pollen diagram of the type locality. The faunal remains from Belvédère indicate more distinct interglacial conditions, just as those from a Saalian ice-pushed clay-layer in the pit Wageningen-Fransche Kamp, in the central part of the Netherlands (Van Kolfschoten, 1991). This layer yielded faunal as well as floral remains which indicate full interglacial conditions. The micromammals indicate an Early Saalian age; the evolutionary stage of the *Arvicola* molars from Wageningen-Fransche Kamp correspond with that of the molars from Maastricht-Belvédère Unit IV. The palynological data, however, do not indicate a definitive age, and the estimates range from 'Cromerian IV' to 'Intra-Saalian' (de Jong, 1991). The problems met in correlating the warm phase of Wageningen-Fransche Kamp to the Dutch Middle Pleistocene stratigraphy demonstrate that the "best fit" solution, a correlation of the Belvédère Interglacial with the Hoogeveen Interstadial, remains problematic. It is for this reason that we have decided to give the interglacial at Belvédère its own, local name.

It is very well possible that the timespan between the Elsterian and the Saalian ice-advance in particular, is more complex, as is shown by the problems met in correlating other Middle Pleistocene warm-temperate periods (van Kolfschoten & Roebroeks, in prep.). For the time being, however, one can confidently state that the Belvédère Interglacial dates from the later part of the Middle Pleistocene, a timespan which is stratigraphically still not well known.

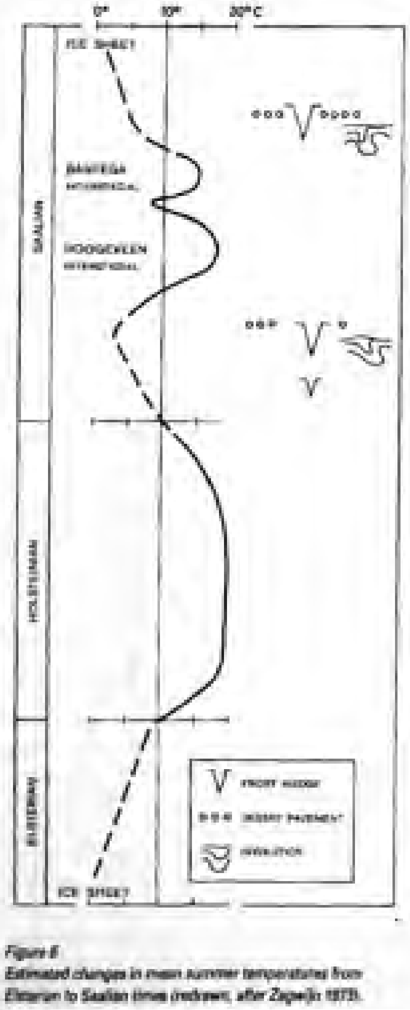


Figure 6
Estimated changes in mean summer temperatures from Elsterian to Saalian times (redrawn, after Zagwijn 1975).

The Oxygen Isotope record

The complexity of the climatical history of the Middle and Late Pleistocene is well documented in the deep-sea oxygen isotope record. Correlating the isotope stages to the continental subdivision of the Pleistocene is still problematic. For instance, there is no agreement about the correlation of the Holsteinian Interglacial to the isotope record. The options range from Stage 7 (Linke et al., 1985;), Stage 9 (Zagwijn, 1989), Stage 11 (Kukla, 1978; Sarntheim et al, 1986) and Stage 13 (Kukla, 1975) to stage 15 (Thome, 1990). The different options are to a large extent the result of the enormous variation in radiometric dates of 'Holsteinian' deposits. The results of the different dating methods (ESR, TL, ArAr, K/Ar) are often not consistent and sometimes very contradictive. In spite of this the 'absolute' dates are very often used to correlate with the oxygen isotope record. One should, however, be aware of the reliability of the "absolute" data and try to use these data in combination with other stratigraphical information. The correlation of continental deposits with the continental subdivision should in this aspect still be an important aim.

The radiometric dates for the Belvédère Interglacial, mainly based on TL-dates of burnt flints, indicate a correlation with Stage 7 (Figure 7). The oxygen isotope peak of Stage 7 as compared to those of Stages 1 (Holocene), 5 and 9, is low and this is probably due to the presence of a more extensive ice cap on the Northern Hemisphere and a relatively low sea-level during Stage 7 (Shackleton, 1987). One would expect that a low sea-level was conductive to more continental climatic conditions in our area. In fact, Zagwijn (1989;1991) has recently stressed the existence of two types of interglacials in the Middle and Late Pleistocene of Europe: (1) interglacials with a high sea level, marine transgressions into coastal low-

lands, an oceanic climate similar to or warmer than the present one, with vegetation and climate uniform over large areas; (2) interglacials of a more continental type, with low sea level. The Eemian and the Holsteinian are typical examples of the first type, while the early Weichselian interstadials are of the second type.
In the climatic optimum of the Belvédère Interglacial, however, continental conditions do not prevail; on the contrary, the upper part of the Unit IV deposits contains a rather 'oceanic' mollusc-fauna. This poses some problems for the correlation of the Belvédère Interglacial with the low sea level Stage 7. At the moment, however, this correlation seems to provide 'the best fit'.

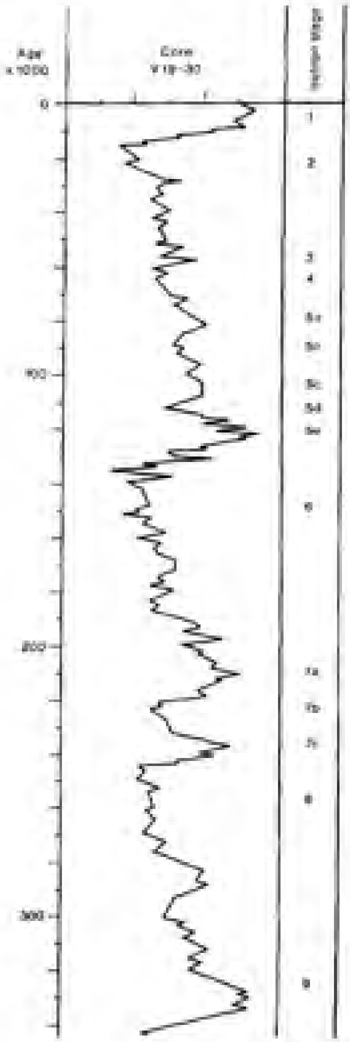


Figure 7
Oxygen isotope stratigraphy core V19-30, showing stages 1-9 and age estimates for stages boundaries (redrawn after Shackleton and Pisias 1985, by courtesy of N. Shackleton).

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