

Palaeohydrologic conditions in the Mark River basin during the last 15,000 years

Willy Huybrechts¹

Geographical Institute, Free University Brussels, Pleinlaan 2, 1050 Brussels, Belgium; ¹Present address: Laboratory of Hydrology, Free University Brussels, Pleinlaan 2, 1050 Brussels, Belgium

Received 12 November 1987; accepted in revised form 21 November 1988

Key words: Alluvial sedimentary environment, Palaeohydrology, Fluvial incision, Holocene, Late Glacial

Abstract

This paper presents an outline of lithologic and morphologic developments in the alluvial environment of the Mark Basin in Central Belgium during Post Glacial times. By means of about 900 borings the spatial arrangement and stratigraphic position of palaeomorphologic features and sedimentary units in different parts of the basin was reconstructed. This, together with the radiocarbon datings, offers an insight into Holocene palaeohydrologic conditions in the Mark River floodplain. The influence of prevailing topographic and geologic conditions in the basin, and changes in external factors, such as climate and man, on the developments in the floodplain are evaluated.

1. Introduction

The evolution of most river basins in northern and central Belgium is characterised by periods with predominantly erosional activities, alternating with periods where aggradation was more important. Rivers, in response to the prevailing external conditions (climate, man), at certain moments scoured new valleys or channels which were later filled again by sedimentological processes. In some basins this occurred rather repeatedly, giving rise to sometimes complex systems of palaeovalleys and/or palaeochannels of different ages. Usually these morphological phenomena are no longer visible in the present-day alluvial landscape, covered as they are by younger alluvial deposits.

This paper deals with a Post Glacial palaeovalley system which was detected in the alluvial plain of the Mark River in Central Belgium, located about 30 km southwest of Brussels. The Mark River basin

(Fig. 1) covers approximately 170 km² of a gently undulating landscape between 20 and 110 metres above sea level. The geology of the area is dominated by subhorizontal, Eocene sand and clay layers, that are overlain by a loess mantle of varying thickness. In the valleys Pleistocene sands and silty sands, as well as Holocene deposits accumulated, giving rise to a well-developed floodplain that can attain a width of 1 km in the downstream area.

An extensive boring campaign, resulting in nearly a thousand borings, was executed between 1978 and 1984, extending over the floodplain of the Mark River from source to mouth. It enabled to describe, in a detailed way, palaeomorphological and lithological phenomena, and to elaborate their three dimensional distribution in the alluvial deposits.

Changes in the environmental conditions in time and space, in the river basin and especially in the floodplain after the last climatic minimum, gave

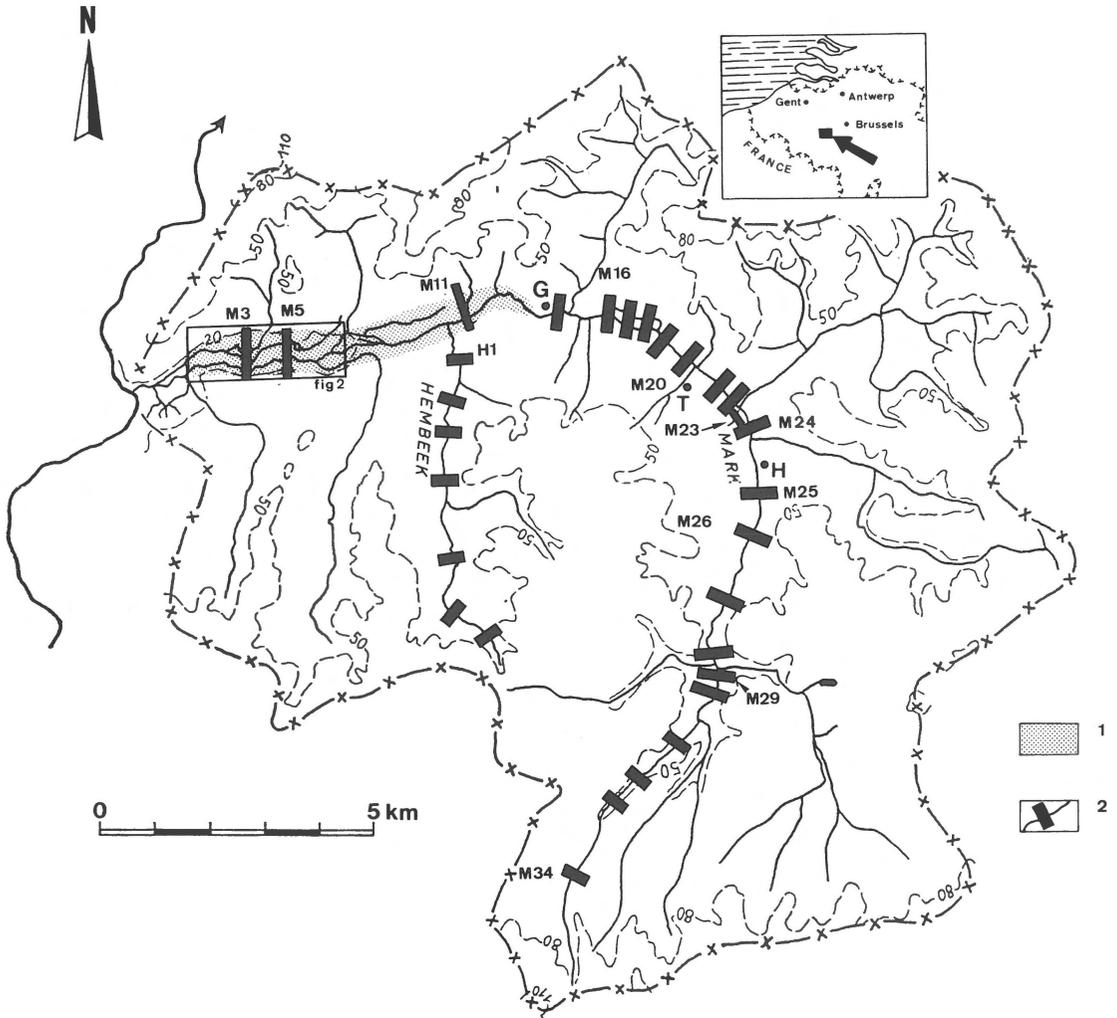


Fig. 1. Location map. 1: boring network; 2: cross section; G. Galmaarden; T. Tollembeek; H. Herne.

rise to a wide variety of sediments. Their composition and internal lithological variation, their spatial extent in the alluvial complex and finally their age are discussed in this paper. Special attention is paid here to valley cutting and filling mechanisms, governed by external (climate and man) and local factors (topography and geology), and to their impact upon the morphological and sedimentological behaviour of the Mark River system.

2. The palaeovalley and its fill deposits

The alluvial deposits of the Mark River can be subdivided into eight major lithogenetic units (Huybrechts 1985a) each of which represents a specific phase in the floodplain development. They can be easily distinguished from one another and are clearly recognised in borings (Table 1). Since they have a significant lateral development they can be traced and mapped throughout the alluvial complex by means of borings.

In this way, the spreading of each of the lithogenetic units is rather accurately known. This is espe-

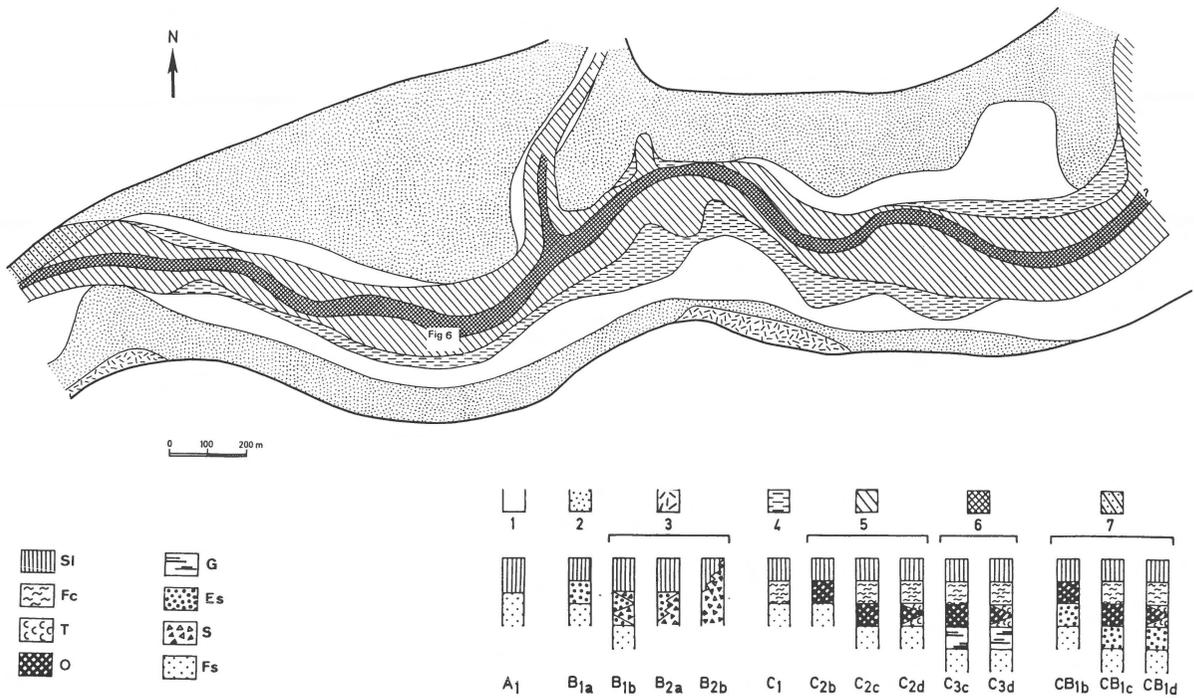


Fig. 2. Profile type map of the alluvial deposits. Fs: Fluvial sand facies; S: Slope facies; Es: Eolian sand facies; G: Gully facies; O: Organic facies; T: Tufa facies; Fc: Fluvial clay facies; SI: Surface loam facies.

cially true for the area downstream of Galmaarden, for which a detailed map (Fig. 2) is available. 34 Cross sections, evenly spaced along the river course at mean intervals of 650 metres, offer an

insight into the vertical construction of the fill deposits. A selection of these cross sections is presented in Fig. 3 (Huybrechts 1985a).

The Palaeovalley

The map (Fig. 2) shows a meandering system in the centre of the floodplain, which is about 150 to 200 metres wide and receives a small tributary from the north. The thalweg of the system is situated within zone 6, which delimits the extent of unit IV.

The palaeovalley is for the greater part eroded into fluvial sands (unit I) of Pleistocene age (Paepé & Van Hoorne 1967, Tavernier & De Moor 1974, Haesaerts & De Heinzelin 1979). However, at some places, valley walls may be built up of the Eolian sand facies (unit III) or of the Slope facies (unit II). The paleovalley was cut after the deposition of the Eolian sand facies on top of unit I. The Eolian sand facies once covered most of the floodplain, but a broad belt (zone 1 and 3 to 7 on Fig. 2) was eroded during the first phase of the development of the valley (Huybrechts 1985b).

The shape of the valley may differ considerably

Table I. Lithogenetic units in the Mark alluvium

Unit I:	Fluvial sand facies (Fs), grey to greenish-grey graded sands.
Unit II:	Slope facies (S), stratified loam to sandy loam.
Unit III:	Eolian sand facies (Es), yellow to yellowish brown sand to silty sand.
Unit IV:	Gully loam facies (G), sand to sandy loam with distinct lamination at the base, grows finer towards the top (silt to clay).
Unit V:	Organic facies (O), a highly organic sediment varying from wood peat to clayey peat and peaty clay with many wood fragments.
Unit VI:	Tufa lime facies (T), white to light brown calcium carbonate particles, fine to coarse grained.
Unit VII:	Fluvial clay facies (Fc.), a green to grey weak clay with vivianite and plant debris.
Unit VIII:	Surface loam facies (SI), brown to greyish brown loam, sandy near the river and clayey in the flood basin.

N

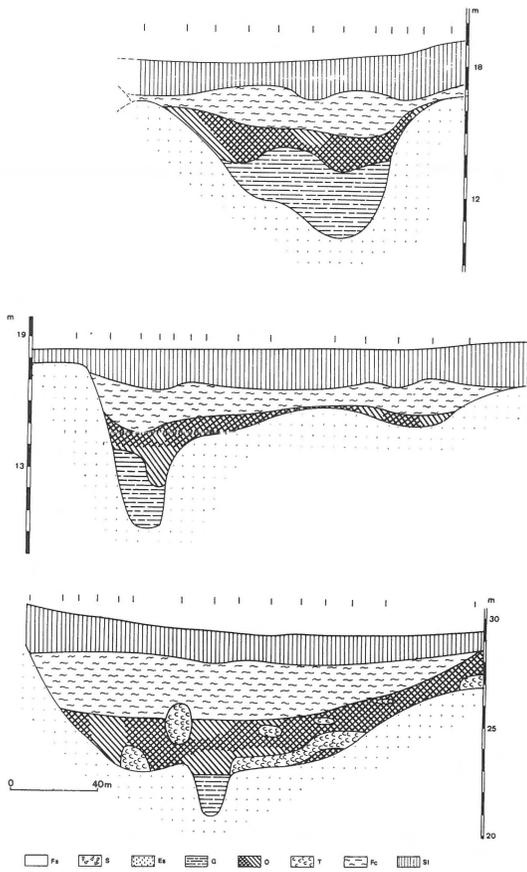


Fig. 3. Cross sections M3, M5 and M24. Fs: Fluvial sand facies; S: Slope facies; Es: Eolian sand facies; G: Gully facies; O: Organic facies (peat, peaty); T: Tufa facies; Fc: Fluvial clay facies; Sl: Surface loam facies.

from one place to another. These variations do not exhibit a clear pattern. Depth and width for instance do not diminish systematically in the upstream direction. On the contrary, between the river mouth and Herne (Fig. 1), the depth is rather constant and at Herne the width of the valley even exceeds that of more downstream areas. Upstream of Herne width and depth of the valley do decrease more or less progressively. The morphological variability in large part depends upon local conditions during the river incision. In cross section M5 (Fig. 3) for instance, river erosion first shifted from south to north in the floodplain, creating an undercut slope at the outer bend of the valley meander.

S

Here, the position of the river stabilized thereby cutting a deep and narrow valley. Elsewhere, the position of the river was less stable as the incision proceeded, giving rise to a wider valley with smoother walls (M3) or to a valley with a flat bottom (M24), as occurs systematically between Tollembeek and Herne (Fig. 1). This is one of the reasons, why no clear relation exists between the cross-sectional area of the palaeovalley and the drainage area, as shown in Fig. 4.

M3

The fill deposits

The fill deposits of the palaeovalley are made up of four lithogenetic units: units IV to VII. Although their relative importance may differ from one place to another, their position in the fill deposits is always the same. They exhibit an arrangement of three lithological phases of infilling: first the Gully facies, then the Organic facies together with the Tufa lime facies and finally the Fluvial clay facies (Fig. 3). The distribution of these three phases in the downstream area of the alluvial plain of the Mark river, can be read from Fig. 2. They are represented by zones 6, 5 and 4.

M5

M24

The Gully facies

The Gully facies (unit IV) occupies the bottom part of the palaeovalley. In the area downstream of Moerbeke (M3 and M5) it is responsible for the greater part of the vertical filling of the valley and can reach a thickness of 3 to 4 metres. However, the importance of the Gully facies for the filling of the valley, decreases gradually in the upstream direction. Above Galmaarden (see M24 in Fig. 3), its appearance is confined to a 20 m wide and 2 m deep gully that is cut into the flat valley bottom. Further upstream it is also growing thinner, and finally disappears completely close to a convex knickpoint in the palaeo-longprofile (Fig. 5), where the palaeo-gradient becomes higher than 0.27%. It is a structural knickpoint related to a volcanic dyke that crops out through the Eocene sand and clay layers which dominate the geology of the Mark basin. The Mark River cuts through this volcanic dyke 250 m downstream of M29.

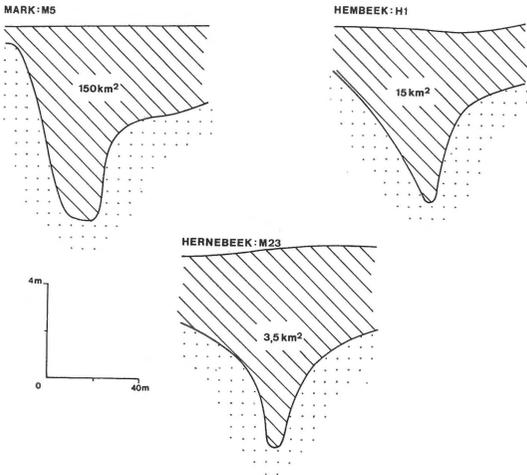


Fig. 4. Palaeovalleys of the Mark River, Hembeek and Hernebeek, with drainage area indicated.

The Organic facies and the Tufa facies

A second lithological phase in the infilling of the palaeovalley includes two lithogenetic units: the Organic facies (unit V) and the Tufa facies (unit VI). As is shown in the cross sections of Fig. 3, the Organic facies, mainly woodpeat, is definitely the dominant component in this phase. The Tufa facies

occurs in lenses of varying shape and dimensions, which are incorporated in the Organic facies. The position of these lenses may change considerably from one place to another; they can appear either at the top or near the bottom of the peatlayer, in the centre of the valley or nearer the flank. The Tufa facies is particularly abundant in the middle reach of the Mark River (M20 to M25), where several affluents join the main course. The smaller rivers seem to play an especially important role in the supply of lime to the Mark alluvium. In their lower reaches the second phase consists mainly of the Tufa facies, while the Organic facies is reduced to several smaller lenses, dispersed in the infilling.

In the centre of the palaeovalley, where it overlies the Gully facies, the Organic facies is generally about 2 to 3 m thick, but exceptional thicknesses of 5 m occur. The Organic facies gradually thins towards and up the valley walls, where it rests directly upon the Fluvial sand facies. At places, where valley walls are rather steep, wedging is very sudden; elsewhere, generally at the inner curves of the valley meanders, where slopes are more gentle, it occurs more gradually. Here the Organic facies exhibits a much greater lateral extension in the floodplain than does the first phase (M5). The

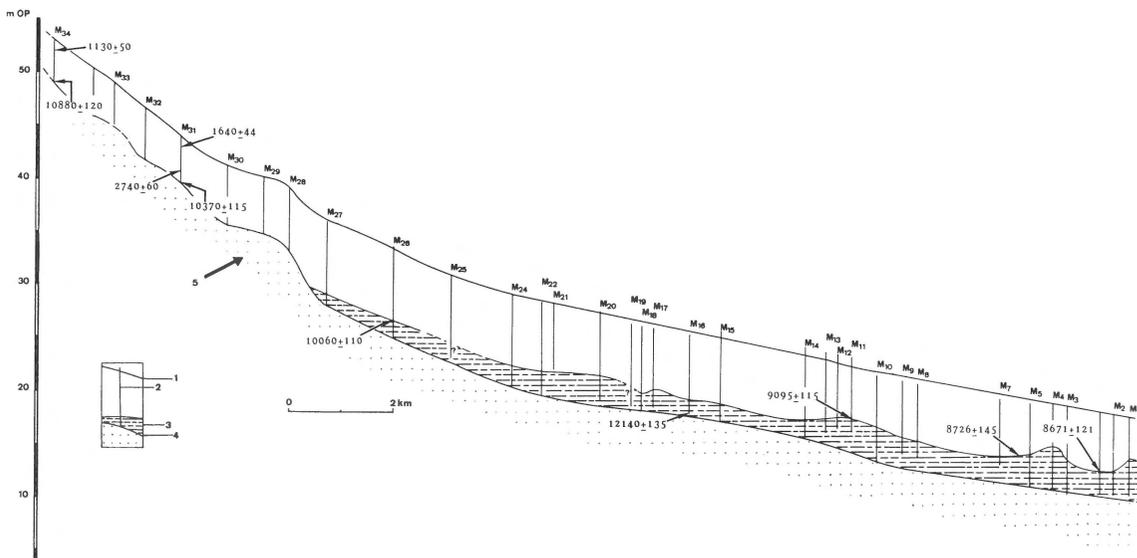


Fig. 5. Length profile of the Mark alluvium. 1: riverplain; 2: cross section; 3: Gully facies; 4: Palaeo-longprofile; 5: knickpoint. Dates in ^{14}C y. B.P.

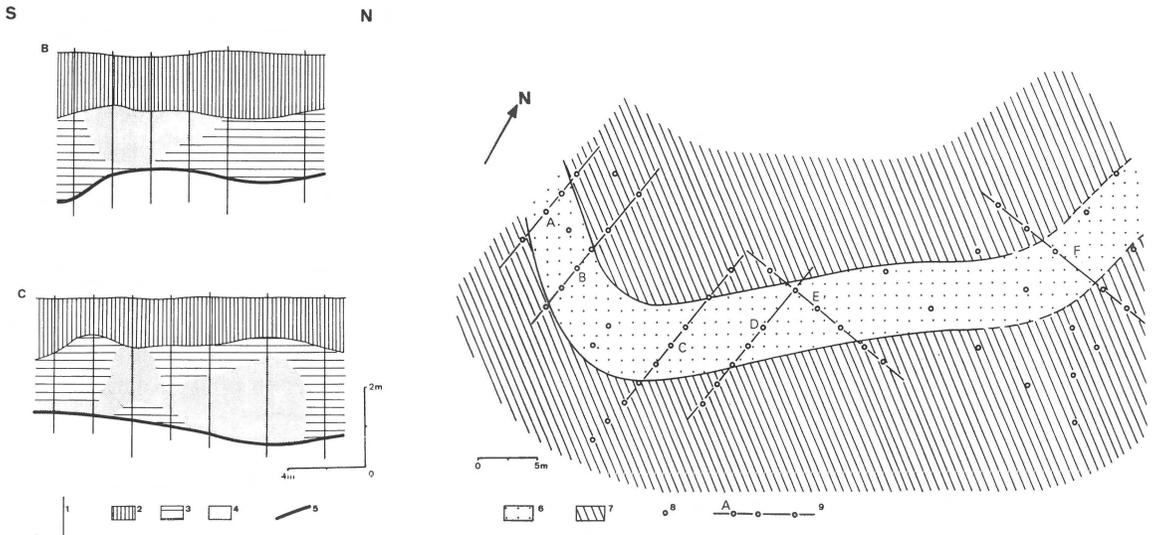


Fig. 6. A streamchannel in the Fluvial clay facies. 1 and 8: boring; 2: Surface loam facies; 3 and 7: clayey Fc facies; 4 and 6: sandy Fc facies; 5: top of Organic facies; 9: Cross section.

boundary between the Gully facies and the Organic facies generally coincides with a more or less sudden widening of the valley. This can be seen in M5 and M3, but can be best demonstrated in M24 and M26 (Figs. 3 and 6). Here, where the gully in the flat valley bottom is filled and where the palaeovalley widens dramatically, the facies changes abruptly.

Although the Organic facies always contains a certain amount of clastic material, it can be considered as relatively pure in the downstream area. Upstream of M24, however, intrusions of important clastic bodies appear more frequently. The Organic facies finally disappears at the knickpoint near M28 where the valleyfill becomes completely clastic. Traces of the Organic facies reappear further upstream, but only as peatlenses of varying dimensions and no longer as a continuous body.

The Fluvial clay facies

The depression-like shape in the top of the peat-layer is filled completely during the third and last phase of infilling: the Fluvial clay facies (unit VII). This phase can reach a thickness of 5 m but generally fluctuates between 2 and 3 m. Its lateral extension corresponds with the maximum dimensions of the palaeovalley, and after its deposition the

palaeovalley is no longer perceptible in the field. As a consequence, the deposition of unit VIII (Surface loam facies) and the location of the river channel at that time, is completely independent of the preceding morphological situation. Although the main component of unit VII is a soft clay with a large amount of vivianite, it also contains sand. These sands occur in thin layers that are widely dispersed in the vast clay body. However, at one place, the sands are very abundant and attain a considerable thickness. A detailed mapping around this spot revealed the existence of a winding, channel-like sandbody (Fig. 6), clearly cut into the surrounding clay sediments. It can be followed over a length 50 metres, but beyond this, the sands are again scattered and lost in the clay body.

In the upstream areas of the basin, the clear three-fold composition as described above, can no longer be distinguished. The Gully facies has disappeared completely and although there are still organic deposits, the Organic facies is no longer present as a continuous body. In a way the sedimentary structure of the infilling deposits is much more complex and difficult to unravel by means of borings. Although it consists predominantly of silts and clays, the infilling is rather heterogeneous and often

shows an irregular mixture of a wider range of sediments. Vertical and lateral changes in composition are very abundant.

3. Radiocarbon dating

A total number of 32 radiocarbon dates describe the age of the sediments of the palaeovalley (Huybrechts 1985a); 19 dates¹ are discussed in this paper. They mainly refer to the Organic facies, as the organic content of the other units is generally insufficient for the application of radiocarbon dating.

However, one date could be obtained for the Gully facies in cross section M16 (Figs. 5 and 7) where, very exceptionally, a 11 cm thick peatlayer occurs at the base. The bottom 2.5 cm of this peatlayer was dated: $12,140 \pm 135$ BP (IRPA 619).

The top and the base of the Organic facies were dated several times. Cross sections M11 and M26 in Fig. 7, show that peatgrowth is not related to a specific period of time; its age changes from place to place according to palaeomorphological conditions. The base as well as the top of the Organic facies become younger higher up both valley sides, where it is resting on the Weichselian sands. In M11, ages range from 9095 ± 115 BP (IRPA 484), via 5770 ± 75 BP (IRPA 551) to 3260 ± 60 BP (IRPA 548) for the base and from 4300 ± 65 BP (IRPA 549) to 2580 ± 65 BP (IRPA 506) for the top of the layer. The initial replacement of the Organic facies by the Fluvial clay facies in the centre of the valley was not dated in M11. Results from other cross sections suggest that for the downstream area this replacement occurred around 6000 BP: 5538 ± 95 BP² (5800 ± 95 BP, IRPA 440) and 6171 ± 115 BP² (6710 ± 100 BP, IRPA 443).

Further upstream in M26, directly below the convex knickpoint, several larger clastic bodies are incorporated in the Organic facies. The accumulation of organic debris was already temporarily interrupted in the centre of the valley as early as

8890 ± 95 BP (IRPA 553). This was repeated several times afterwards and finally the Organic facies was definitively replaced by the Fluvial clay facies at 7620 ± 90 BP (IRPA 552) in the centre of the valley and at 3080 ± 60 BP (IRPA 569) on the western valley wall. The age of the base of the Organic facies ranges from 10060 ± 110 BP (IRPA 554) to 6050 ± 75 BP (IRPA 570). The peatlenses on the eastern valleywall are of much younger age: between 2390 ± 55 BP (IRPA 556) and 870 ± 50 BP (IRPA 655).

Datings in the upstream region (M34), reveal that although the first infilling could be dated around 10 000 BP the major part of the deposits is much younger. A serious time gap exists between the humic deposits at the bottom of the palaeovalley ($10,880 \pm 115$ BP, IRPA 643) and the peat lenses higher in the fill deposits (1130 ± 50 BP, IRPA 544).

4. Palaeohydrologic conditions in the Mark River basin

The scouring of the palaeovalley is one of the major events in the morphological development of the floodplain of the Mark River. The palaeovalley came into existence before 12,000 BP and did not disappear from the landscape until approximately 1400 BP.

In fact the morphology shown in Figs. 2 and 3 can be interpreted to be either a palaeovalley or a palaeochannel. The text above indicates that the author considers this feature to be the result of a vertical incision of the river, accompanied by a lowering of the water table in its immediate surroundings. Indeed, the disproportion between the dimensions of the palaeovalley and the dimensions of the basin is too pronounced to allow a channel interpretation (Schumm 1977). Even the lowest discharge estimates based on dimensions and sinuosity of the 'channel' (cf. Rotnicki 1983) would require a precipitation of more than 1000 cm per year. The most important argument, however, is that where the affluents of the Mark River enter the main floodplain, the depth of their palaeovalley equals that of the Mark Valley. This is even so for

¹ all dates in radio carbon years Before Present.

² corrected date for the actual top or base of the layer, when sampling was done over a wider thickness due to a low organic content hereby the mean speed of peat accumulation in that boring was taken into account.

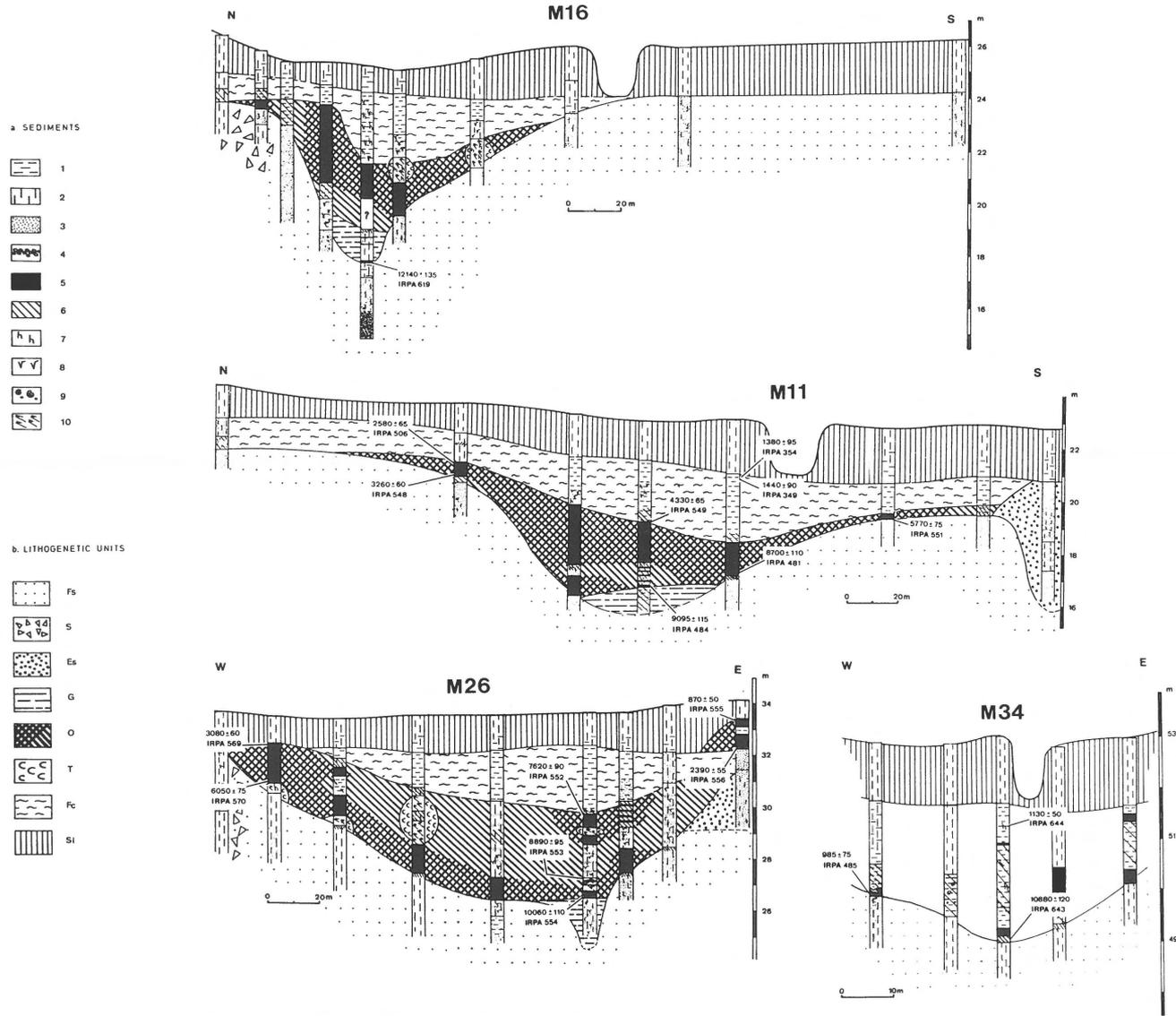


Fig. 7. Cross sections M11, M16, M26 and M34 with radiocarbon dates in ^{14}C y. B.P.

1: clay; 2: silt; 3: sand; 4: gravel; 5: peat; 6: organic; 7: wood; 8: plant debris; 9: shells; 10: Tufa. Fs: Fluvial sand facies; S: Slope facies; Es: Eolian sand facies; G: Gully facies; O: Organic facies (peat, peaty); T: Tufa facies; Fc: Fluvial clay facies; Sl: Surface loam facies.

very small basins of merely 3,5 km² (Fig. 4). The depth of the palaeovalley in its lower course is extremely disproportionate to the basin size. This can only be understood when a lowering of the water level in the Mark floodplain is involved.

As the palaeovalley was eroded into Pleistocene sediments and as the infilling of the valley started before 12,000 BP, it must have been formed during the climatic transition from Pleniglacial to Late Glacial. This same period of intensive fluvial erosion was observed in many other riverbasins in Belgium (Mullenders & Gullentops 1956, Verbruggen 1971, Tavernier & De Moor 1974, Haesaerts 1984). However, no precise date for the beginning of this erosional phase could be established in any of those basins, nor is there any information available concerning duration of that period. Datings are always obtained from fill deposits.

Cleveringa et al. (1988) proposed a hydro-climatological cause to explain this erosion phase. At the transition of Pleniglacial to Late Glacial, when climatic conditions improved from continental cold to oceanic warm (with a rise in temperature and precipitation), vegetational development lagged behind climatic change. Low evapotranspiration and high precipitation rates led to a serious disturbance of the waterbalance, resulting in high water discharge. If under these conditions slopes in the catchment are stabilized to a sufficient degree so that sediment discharge does not rise to the same extent, then the alluvial plain can be strongly eroded (Knox 1972, Schumm 1977, Starkel 1983).

According to others (Tavernier & de Moor 1974, De Moor 1984) the erosional phase at the transition from Pleniglacial to Late Glacial times is related to the low sea level at that time. Although this might have been an important fact when the erosion proceeded, in the case of the Mark River the longitudinal profile does not provide arguments to consider a lowering of the erosion base as the driving force behind these processes.

As stated above it is not known when exactly the erosion started and how long it took to scour the valley. However, up to 12,140 ± 135 BP the river was still active enough to prevent any important sediment build-up in the valley. From then onward, the fluvial activity diminished to a sufficient

extent so that sedimentation became possible. As vegetation grew denser, discharges lowered due to a higher evapotranspiration. In the upper reaches of the valley the period of non-deposition lasted 2000 years longer, until 10.000 BP. In the meantime unit IV (Gully facies) developed in the downstream area, which took about 3000 years, from 12000 BP to 9000 BP. A gradual lowering in fluvial activity during this period can be read from the fining of the sediments from bottom to top. Clear evidence for a reactivation of erosion during the Younger Dryas, as was denoted in several other basins (Van der Hammen & Wymstra 1971, Verbruggen 1971, De Smedt 1973, De Gans 1981) is not available for the Mark River basin.

The decrease in fluvial activity during Late Glacial and the beginning of the Holocene reached a critical point around 9000 BP, and led to a change of facies in the downstream area. Due to the development of a dense vegetation in the basin as the climate improved, run off and sediment production were so low that accumulation of detritus (woodpeat) became possible in the floodplain. However, the distribution of the Organic facies in the basin shows that local conditions were also important, more particularly in the relationship between river activity and the dimensions of the floodplain at that time.

In the upstream regions, where river slope was higher than 0.27% the Organic facies developed poorly. The Mark River continued dominating its floodplain and reworked the fill deposits for an extended period, so that mainly clastic deposits accumulated. Smaller organic bodies may have been incorporated, but they appear more lateral in the valley and are much younger (generally post 3000 BP). Near the structural knickpoint (M28), organic debris did not accumulate at all, not even during the climatic optimum in the Atlantic.

The base of the Organic facies often coincides with a more or less drastic widening of the palaeovalley. This can be noticed in M3 and M5, but is extremely clear in M24 and M26. When the small channel in the flat-bottomed valley is filled with sediments, the river suddenly meets a very wide valley, water velocities drop and the accumulation of organic debris can start. In principle this might

happen at any particular moment in time, so that deviations from the 9000 BP data can be expected. In M26, for instance, the organic accumulation started 1000 years earlier than in the downstream area.

From 9000 BP onward, very stable conditions dominated the major parts of the Mark floodplain which was occupied by a marsh-forest. The transport of suspended materials by the Mark River was reduced and nearly all these sediments were deposited upstream of Herne, where larger clastic bodies are incorporated in the Organic facies. The rivers were fed predominantly by sources, and mainly transported dissolved carbonates. After precipitation of these carbonates, mainly due to loss of CO₂ (Gullentops & Mullenders 1971, Marker 1973, Terlecky 1974), particles were transported further downstream where they settled down to form the Tufa facies, lenses of which are incorporated in the Organic facies. Especially smaller affluents delivered large amounts of CaCO₃ to the Mark alluvium. Where the rivers entered the Mark floodplain, the more or less sudden lowering in gradient resulted in an important deposition of CaCO₃. In their lower course the alluvium consists for the greater part of Tufa facies.

For more than 3000 years (9000 to 6000 BP) this situation did not alter considerably. Heightening of the floodplain, and the rise of the watertable were in balance with each other so that a thick peatlayer, with inclusions of tufa, was formed. Due to the constant rise of the water table, conditions for the accumulation of organic matter improved also higher on the valley walls and the area of peat formation increased progressively as time went on. At a certain moment the simultaneous rise of ground level and water level was disturbed, which led to the deposition of the Fluvial clay facies. Radiocarbon dates show that the transition from Organic facies to Fluvial clay facies does not correspond with a particular moment in the development of the floodplain, but that it is spread over a larger period of time and is highly dependent upon palaeomorphological conditions. The process started in the centre of the palaeovalley around 6000 BP.

The continuing rise of the water level, also after

this date, can be read from the radiocarbon dates. It made peat accumulation possible on higher grounds on the valley walls. Therefore, a drying out of the habitat, leading to a higher decomposition rate of the Organic debris, to explain the end of the peat formation in the centre of the valley can be excluded. The Atlantic forests in the floodplain were very well adapted to wet conditions. However, when water level rises above ground level, and stays there all year round, the lack of oxygen for the roots will cause a degradation of the forest and will prevent regeneration as seeds do not germinate (McVean 1953, Dethioux 1972). McVean (1955) showed that germination tests of *Alnus* when under water and covered with sediments (0.5 cm) gave the worst results. Sediment deposition alone also hinders the reproduction of *Alnus*, but in the floodplain of the Mark River, sedimentation rates were too small (less than 1 mm per year) to be the only factor. As a result, the marsh-forest disappeared and the input of organic matter in the alluvial deposits diminished, while on the other hand sediment load of the river increases. The abundance of vivianite in the Fluvial clay facies also indicates that very wet conditions prevailed and that this unit was deposited under water.

From this it can be concluded that from 6000 BP onward, in certain parts of the floodplain, water level rose above topographical level. Due to the stable regime it stayed there all year round and an open water situation was created. In the course of time the open water area increased, pushed the marsh-forests to the side of the valley, and finally dominated it completely.

In this flooded river plain, confined stream and currents were active which transported and supplied sediment to deposition centres. At one place a stretch of these streams could be traced and reconstructed (Fig. 6). The coarse sandy load settled close to the streamlines, while the suspended load, mainly clay, spread out over the floodplain and settled down in calm conditions. In most parts of the floodplain, the streamlines exhibited an important mobility and widely dispersed sandy material in unit VII, so that they no longer can be traced.

As for the external factors governing these distinct changes in the sedimentary behaviour of riv-

ers in Northern and Central Belgium during the Atlantic period, two mechanisms have been suggested, a climatological and an antropogenetic one. Gullentops (1957), De Ploey (1961) and De Heinzelin et al. (1977) decided in favour of a climatological explanation, more particularly a rise in precipitation, which resulted in increased run off and erosion in river basins. However, it has been stated earlier (Langbein & Schumm, 1958) that when the basin is covered with a dense vegetation, a rise in precipitation has little effect on sediment yield. Based on the study of permanently wooded areas in Belgium, Langohr & Sanders (1985) came to the conclusion that no important erosion of slopes took place during the Atlantic as long as forest persisted. An at least partial degradation of the vegetation seems necessary to explain an increase in the sediment load of the rivers.

These conditions are fulfilled in the second hypothesis, where man is thought to be responsible for the Atlantic alluviation (Mullenders et al. 1966, De Heinzelin et al. 1977, Froehlich et al. 1977). Scattered and rather reduced deforestations of Neolithic man for agricultural purposes could have led to an increased run off and erosion in the basin and consequently to a higher water level in the floodplain and hence to the deposition of the Fluvial clay facies. The relation between human occupation, forest degradation, slope erosion and finally Atlantic alluviation from 6000 BP onward, has been convincingly demonstrated by Paulissen et al. (1981). For the Mark River it is significant that the oldest Neolithic settlement in the Dender basin, of which the Mark River is a part, was occupied before 6000 BP (Cahen & Gilot 1983), most probably between 6200 and 6000 BP (Cahen & Van Berg 1979). This agrees very well with the start of the alluviation in the floodplain.

The deposition of the Fluvial clay facies went on until at least 1400 BP. Shortly after this date the palaeovalley system was completely filled and disappeared from the alluvial landscape. The Surface loam facies (unit VIII), which was deposited independently of the palaeovalley system, covers the complete floodplain and is related to the present-day position of the Mark River.

It is generally accepted that unit VIII was depos-

ited during high winter floods, when the Mark River inundated its floodplain. The natural levees of the Mark River system are made up of these sediments, which exhibit a decreasing grainsize from the river to the floodbasin. As opposed to the Fluvial clay facies, when a stable regime reigned to provide a permanent high water level, the Surface loam facies is related to an unstable regime with high water and low summer discharges. The vast deforestations in Medieval times, especially between 800 and 1200 AD are responsible for the destabilisation of the natural river regime that had, until then, led an undisturbed existence from (at least) the beginning of the Holocene.

5. Conclusions

The palaeohydrological and sedimentological evolution of the Mark basin during the last 15,000 years has been dominated by the development of a palaeovalley system. It resulted from a vertical erosion of the Mark River at the transition from the Pleniglacial to the Late Glacial and has affected the whole basin. During more than 10,000 years Pleistocene deposits in the present-day floodplain occupied a terrace position, and fluvial action was constrained to the palaeovalley. The infilling of the valley reflects the changing climatic and antropogenetic conditions which affected the alluvial environment during post glacial times. Detailed mapping and a three dimensional reconstruction of the distribution of these fill deposits and their dating as a function of palaeomorphological conditions, form a basis for the reconstruction of palaeoenvironmental and palaeohydrological conditions that prevailed in the floodplain during that period.

Plant cover occupies a central position in the water balance of a river basin. As such, it determines to a large extent morphological and sedimentological activities of the river and sediment yield in the basin. Several examples show that the influence of external factors, such as climate and man, on the behaviour of the river mainly acted through the vegetation. The development of the Palaeovalley for instance is thought to be related to a time lag between climatic improvement and the

recovery of the vegetation after the Pleniglacial. When the density of the plant cover reached a certain level, the lithology of the fill deposits changed from clastic to organic, so that sediment yield was minimised by complete stabilization.

From 6000 BP onward, man determined sedimentary behaviour of the Mark River by clearing these dense Atlantic forests for agricultural purposes. During a first phase, reduced and scattered deforestations by Neolithic man resulted in a drowning of the floodplain and created an open water situation. This changed again when the cumulative effect of deforestation reached a critical point and destabilization of the river regime occurred. It gave rise to an inundating type of river with overbank deposition as we know it at the present day.

On the other hand it could be demonstrated that local conditions (topography and geology) played an important part in the translation of climatic and anthropogenic signals into sedimentological and morphological action by the river. These local conditions determined when and where threshold conditions were exceeded whereby parts of the basin did not react in the same way.

The infilling process for instance, started significantly later in the upstream regions and the sedimentary units did not develop as distinctly because of repeated reworking by the river. Climatic conditions had been favourable for peat formation during the whole Holocene. However, the Organic facies developed as a continuous body only in the downstream area, and only when the floodplain width was large enough as compared to the activity of the Mark River. It was shown that the age of the Organic facies and the lithologic transition from the Organic to the Fluvial clay facies also significantly depended upon local topography.

It can be concluded that local conditions act as a filter and produce noise with respect to the external factors. These noise producing elements are generally insufficiently understood, which often leads to confusing and sometimes even contradictory results. It is clear that, in order to unravel the climatic and anthropogenic signal embedded in the alluvial deposits, the effects of local conditions and their spatial variability deserve more attention.

Acknowledgements

The author expresses cordial thanks to M. Van Strijdonck of the Radiocarbon Laboratory of the Koninklijk Instituut voor het Kunstpatrimonium for providing the dates.

References

- Cahen D. & P.L. van Berg 1979 Un habitat danubien à Blicquy – *Archaeologica Belgica* 221: 39 pp
- Cahen D. & E. Gilot 1983 Chronologie radiocarbone du Néolithique danubien – *Dissert. Archaeol. Gandenses XXI*: 21–40
- Clevringa P., W. De Gans, W. Huybrechts & C. Verbruggen 1988 Outline of river adjustments in small river basins in Belgium and The Netherlands since the Upper Pleniglacial. In: Lang G. & Schlüchter (Eds.): *Lake, Mire and river environment* – Balkema, Rotterdam: 123–132
- De Gans W. 1981 The Drentsche Aa valley system – Thesis, Amsterdam: 132 pp
- De Heinzelin J., P. Haesaerts & J. De Laet 1977 Le Gué du Plantin – *Dissert. Archaeol. Gandenses XVIII*: 58 pp
- De Moor G. 1984 Fluviaatiele morfologie, dynamiek en evolutie. – In 'Water voor groen'. Vereniging voor groenvoorziening, Brussel: 149–174
- De Ploey J. 1961 Morfologie en kwartairstratigrafie van de Antwerpse Noorderkempen – *Acta Geogr. Lovaniensia* 1: 130 pp
- De Smedt P. 1973 Palaeogeografie en kwartair-geologie van het confluentegebied Dijle-Demer – *Acta Geogr. Lovaniensia* 11: 141 pp
- Dethioux M. 1972 Le semis naturel de l'aunle glutinosa – Notes techniques du centre d'écologie forestière, Gembloux: 13 pp
- Froehlich W., L. Kaszowski & L. Starkel 1977 Studies of present-day and past river activity in the Polish Carpathians. In: Gregory K.J. (ed.): *River channel changes* – Wiley & Sons, Chichester: 448 pp
- Gullentops F. 1957 L'évolution du relief depuis la dernière glaciation – *Bull. Soc. Belg. Et. Géogr.* 26: 71–84
- Gullentops F. & W. Mullenders 1971 Age et formation de dépôts de tuf calcaire holocène en Belgique. In: Macar P. & A.. Pissart (eds): *Processus périglaciaire*. Liège: 113–137
- Haesaerts P. & J. De Heinzelin 1979 Le site paléolithique de Masières-canal – *Dissert. Archaeol. Gandenses XIX*: 129 pp
- Haesaerts P. 1984 Les formations fluviaatiles Pléistocène du bassin de la Haine (Belgique) – *Bull. Ass. française Et. Quat.* 1984: 16–26
- Huybrechts W. 1985a Morfologische evolutie van de rivier- vlaakte van de Mark (Geraardsbergen) tijdens de laatste 20.000 jaar – Thesis, Brussels: 250 pp
- Huybrechts W. 1985b A palaeovalley system in the floodplain of the Mark River (Central Belgium) – *Earth surface processes and landforms* 10: 247–255

- Knox J.C. 1972 Valley alluviation in southwestern Wisconsin – *Ann. Ass. Amer. Geogr.* 62–3: 401–410
- Langbein W.B. & S.A. Schumm 1958 Yield of sediment in relation to mean annual precipitation – *Am. Geophys. Union Trans.* 39: 1076–1084
- Langohr R. & J. Sanders 1985 The Belgian löss belt in the last 20,000 years. Evolution of soils and relief in the Zonien forest – In: Boardman J. (ed): *Soils and Quaternary landscape evolution* – Wiley & Sons, Chichester: 354–366
- Marker M.E. 1973 Tufa formation in the Transvaal, South Africa – *Z. Geomorph.* 17: 460–473
- McVean 1953 Biological flora of the British Isles, *Alnus glutinosa* (L.) Gaertn – *J. Ecology* 41: 447–466
- McVean 1955 Ecology of *Alnus glutinosa* (L.) Gaertn – *J. Ecology* 43: 61–71
- Mullenders W. & F. Gullentops 1956 Evolution de la végétation et de la plainc alluviale de la Dyle, à Louvain, depuis le Pléni-Würm. – *Bull. Acad. Roy. Belg.* 42: 1123–1137
- Mullenders W., F. Gullentops, J. Lorent, M. Coremans & E. Gilot 1966 Le remblaiement de la vallée de la Néthen – *Acta Geogr. Lovaniensia* 4: 169–181
- Paepé R. & R. Vanhoorne 1967 The stratigraphy and palaeobotany of the Late Pleistocene in Belgium – *Toelicht. Verhand. Geologische kaart en Mijnskaart van België* 8: 96 pp
- Paulissen E., F. Gullentops, P.M. Vermeersch, M.-A. Geurts, E. Gilot, W. van Neer, E. van Vooren & E. Wagemans 1981 Evolution holocène d'un flanc de vallée sur substrat perméable (Hesbaye sèche, Belgique) – *Inst. Géol. Univ. Louvain Mém.*, 31: 23–75
- Rotnicki K. 1983 Modelling past discharges of meandering rivers – In: Gregory K.J. (ed): *Background to palaeohydrology* – Wiley & Sons, Chichester: 448 pp
- Schumm S.A. 1977 The fluvial system – Wiley & Sons, Chichester: 338 pp
- Starkel 1983 The reflection of hydrologic changes in the fluvial environment of the temperate zone during the last 15,000 years. In: Gregory K.J. (ed): *Background to palaeohydrology* – Wiley & Sons, Chichester: 448 pp
- Tavernier R. & G. de Moor 1974 L'évolution du bassin de L'Escaut – In: P. Macar (ed): *L'évolution quaternaire des bassins fluviaux de la Mer du Nord Meridionale* – Soc. Géol. Belg., Liège: 159–232
- Terlecky P.M. 1974 The origin of a Late Pleistocene and Holocene marl deposit – *J. Sediment Petrol* 44: 446–465
- Van der Hammen T. & T.A. Wymstra (eds): 1971 The Upper Quaternary of the Dinkel Valley – *Meded. Rijks Geologische Dienst*, ns 22: 55–214
- Verbruggen C. 1971 La morphogenèse de la Vallée Flamance, bref aperçu et quelques aspects nouveaux – *Hommes et Terres du Nord* 1971–1: 61–67