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POST-PLENIGLACIAL FLOODPLAIN SEDIMENTS IN CENTRAL BELGIUM

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(4 figures)

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ABSTRACT. This paper presents an outline of the floodplain sediments which dominated the river environment during the last 13,000 years in the western parts of Central Belgium. It is based on literature, with special reference to the Mark River basin. River landscapes and related floodplain sediments are a combined result of changing external factors such as climate and human activity, and prevailing local geological and topographical conditions. The development of the vegetation predominantly controls the sediment and water fluxes in the catchment. After the Pleniglacial, a system of palaeovalleys developed as a result of a non-equilibrium between vegetation and climate. For more than 10,000 years, this system dominated the river landscape, while gradually being filled with organic material and sediments. Three infilling phases can be distinguished: the Gully facies, the Organic and tufa facies, and the Fluvial clay facies. The Gully facies reflects an initial time period of fluvial activity, and occupies the lowermost parts of the palaeovalley. From 9000 BP onwards, forest swamps occupied the river plains, reflecting very stable conditions in the catchments. The Organic and tufa facies was formed. During the second half of the Atlanticum, from about 6000 BP onwards, human agricultural activities greatly affected the river landscape and the hydrological system. The forest swamps disappeared and were gradually replaced by open water. The deposition of the Fluvial clay facies concluded the filling of the palaeovalley. Medieval clearings in the catchments, less than 1200 years ago, disrupted the originally stable hydrological regime of the river. The Surface loam facies was deposited during inundations, independent of the palaeovalley system.

KEYWORDS. Central Belgium, Post-Pleniglacial, Mark River basin, hydrographic regime, catchment conditions, facies.

SAMENVATTING. Deze bijdrage geeft een overzicht van de sedimenten die de rivieromgeving domineerden gedurende de laatste 13,000 jaar in het westelijk gedeelte van Centraal België. Ze is gebaseerd op literatuurgegevens, met speciale aandacht voor het Markbekken. Rivierlandschappen en de daaraan gekoppelde alluviale sedimenten zijn het gevolg van een combinatie van veranderende externe factoren zoals klimaat en menselijke activiteit, en de heersende geologische en topografische condities. De ontwikkeling van de vegetatie bepaalt sediment- en waterstromen in het stroombekken. Na het Pleniglaciaal ontwikkelde zich een systeem van palaeovalleien tengevolge van een onevenwicht tussen de vegetatieontwikkeling en de klimatologische condities. Meer dan 10,000 jaar domineerde dit systeem het rivierlandschap, terwijl het geleidelijk werd opgevuld met sedimenten en organisch materiaal. In deze opvulling kunnen drie fasen worden onderscheiden: het Geulfacies, het Organisch en tuffacies, en het Fluviatiel kleifacies. Het Geulfacies weerspiegelt een initiale periode van fluviatiele activiteit en neemt de diepste gedeelten van de palaeovallei in. Vanaf 9000 BP bezetten moerasbossen de riviervlakte. Ze zijn het bewijs van stabiele omstandigheden in de stroombekkens, en het Organisch en tuffacies wordt gevormd. Tijdens de tweede helft van het Atlanticum, ongeveer vanaf 6000 BP, bepalen landbouwactiviteiten van de Neolitische mens in sterke mate het rivierlandschap en het hydrologisch systeem. Moerasbossen verdwijnen en worden geleidelijk vervangen door open water. De afzetting van het Fluviatiel kleifacies is de laatste fase in de opvulling van de palaeovallei. Middeleeuwse ontbossingen in de rivierbekkens, minder dan 1200 jaar geleden, ontwrichten het stabiele hydrologische regime van de rivier. Het Leemfacies wordt tijdens overstromingen afgezet, onafhankelijk van de palaeovallei.

SLEUTELWOORDEN. Centraal België, Post-Pleniglaciaal, Mark bekken, hydrologisch regime, stroombekken.

1. Introduction

The present-day landscape in river valleys is the final stage in a long sequence of changing fluvial landscapes. During the last 15,000 years, the vegetation as well as geomorphological, sedimentological and hydrological conditions varied significantly. The changing environmental conditions in river catchments and their floodplains after the last climatic minimum gave rise to a wide range of sediments. The nature and characteristics of the floodplain sediments reflect the hydrological and hydrodynamic conditions that governed the floodplain at the moment of their deposition. They are the result of many factors such as the climatic conditions, activity of man, the geological and topographical setting of the catchment, the size of the catchment, the type of river, the position relative to the river channel, the development of the vegetation, etc. Some of these factors (e.g. the catchment topography and geology) remain more or less constant over time, while others (e.g. climate and human activity) may be subject to considerable changes. On the other hand, a number of the determining factors are uniform over larger areas (e.g. climate) while others have a local character and change from one location to another (e.g. position with relative to the river).

Often the goal to investigate floodplain sediments is to obtain information concerning the hydrological, geomorphological and climatic conditions that dominated the landscape at the moment when the deposition occurred. External factors such as climate and human activity control the net precipitation that is applied to the catchments. The translation of these applications in hydrological behaviour depends on the catchment characteristics. It is obvious that different basins or different parts of a single river basin may exhibit other hydrological responses. Certain external phenomena (e.g. dramatic climatic changes) may be extremely dominant and affect all catchments in a certain region in more or less the same way. This is not necessarily the case with regard to less dominant phenomena, as river catchments are complex dynamic systems. In some cases, the effects of the events may be absorbed by a network of interrelated hydrological processes, so that boundary conditions are not crossed and rivers do not exhibit a clear response, or so that the boundary conditions are crossed at different moments. Local catchment conditions and characteristics thus play an important role (Huybrechts, 1989). Possible different behaviour of rivers due to local conditions of geology and topography should also be taken into account, and care must be taken when extrapolating conclusions outside the scope of the investigations. Also, different sizes of rivers do not respond in exactly the same way, with this being reflected in the sediment construction in the floodplain.

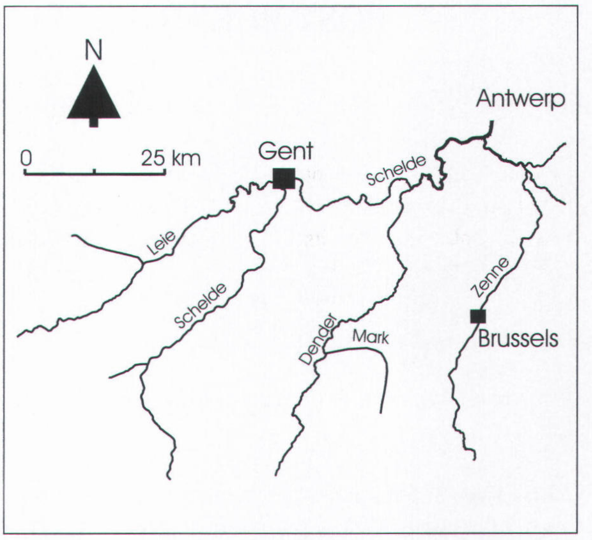

Figure 1. Location of the Mark River basin, western part of Central Belgium.

This paper deals with the floodplain sediments of medium-size river basins (a few hundred square kilometres) in the western part of Central Belgium (Fig. 1). These catchments developed on a Tertiary substratum of alternating marine clay and sand layers, overlain by a loess mantle whose thickness varies. The basin relief varies between 50 and 100 metres. The reference catchment is the Mark river basin, that has an area of 170 km^2 and a well developed floodplain. It is one of the few examples in Belgium, where post-Pleniglacial floodplain sediments have been investigated, paying special attention to the lateral and longitudinal variations in the complete sediment body of the river valley (Huybrechts, 1985; 1989).

The Quaternary floodplain sediments of most river systems in Central and Northern Belgium can be subdivided into two important parts: (1) pre-Pleniglacial and Pleniglacial sediments, mainly consisting of fluvial sands and loam, on some occasions overlain by eolian sands deposits; (2) post-Pleniglacial sediments, dating from the Late Glacial and the Holocene. Both groups of sediments are often separated from each other by an erosion phase (Cleveringa *et al.*, 1988). In this paper, only post-Pleniglacial floodplain sediments are reviewed.

2. The post-Pleniglacial floodplain sediments

This chapter defines and describes the major sediment units that occur in the post-Pleniglacial floodplain sediments of the western part of Central Belgium. It is based on sediment units that have a relatively homogeneous lithological composition and can be easily distinguished from each other. Since they have a significant lateral development, they can be traced and mapped throughout the alluvial complex by means of borings. Their internal lithological variability does not result in sedimentary layers that can be identified or traced in the field. Four post-Pleniglacial sediment units can be distinguished: the Gully facies, the Organic and tufa Facies, The Fluvial clay facies and the Surface loam facies (Huybrechts, 1985).

2.1. The palaeovalley system

The nature, characteristics and especially the spatial distribution of post-Pleniglacial sediments in the floodplain mainly depends on the presence of palaeovalleys. The palaeovalleys are eroded into fluvial and eolian sands of Pleistocene age (Paepe and Van Hoorne, 1967; Tavernier and De Moor, 1974; Haesaerts and de Heinzelin, 1979). In the Mark valley, a meandering system that is circa 150 to 200 metres wide and 8 metres deep can be found (Fig. 2). It was earlier argued (Huybrechts, 1989) that this palaeomorphological phenomenon represents a valley, rather than a river channel. The river was flowing 8 to 10 metres below the present-day floodplain. During the next few thousand years, the river activity, erosion and sedimentation were confined to the palaeovalley system.

The morphology of the palaeovalley may differ considerably from one location to another. A narrow valley exists at some locations, and elsewhere the valley is wide with a flat bottom (Fig. 3). The morphological variability mainly depends on local conditions during the process of river incision. The palaeovalley is present in the whole catchment, from the mouth to very close to the source. In the present-day landscape, the palaeovalley is no longer visible, it is completely filled with post-Pleniglacial sediments.

2.2. The Gully facies

The Gully facies consists of sand and sandy loam, with a distinct lamination at the base, and becomes finer towards the top where it changes to silt or clay. Locally, thin organic layers may be incorporated. The Gully facies occupies the lowermost part of the palaeovalley fill (Fig. 3). In the downstream reaches, it is responsible for most of the vertical filling of the palaeovalley and can be 3 to 4 metres thick. However, the importance of the Gully facies gradually decreases in the upstream direction, where it becomes thinner.

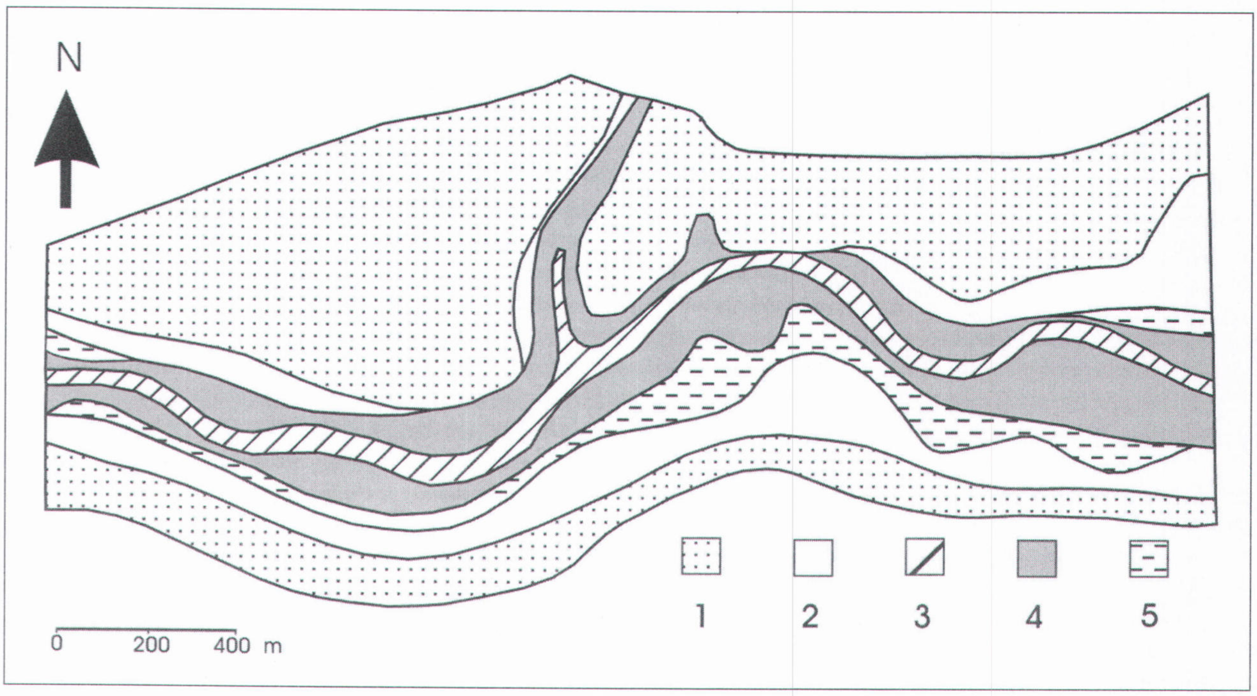

Figure 2. The Palaeovalley system and infillings in the Mark River floodplain (adapted from Huybrechts, 1989). Zone 3 gives the distribution of the Gully facies, zones 3 and 4 of the Organic and tufa facies, and zones 3, 4 and 5 of the Fluvial clay facies. Zone 1 shows the occurrence of aeolian sands, zone 2 the outcrop of fluvial sands. The Surface loam facies that covers the whole floodplain is not shown.

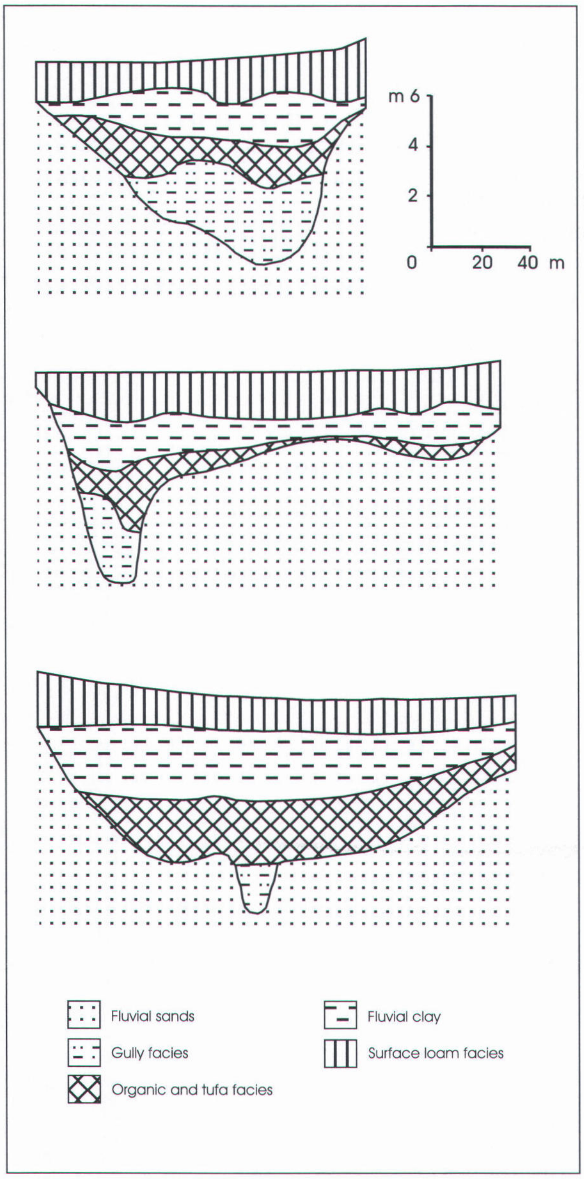

Figure 3. Cross sections of the Palaeovalley system and its infillings in the Mark River basin (adapted from Huybrechts, 1989).

Where the palaeo-gradient is higher, the Gully facies disappears completely. Its lateral extension depends on the morphological characteristics of the palaeovalley. At some locations, it may fill the wide lowermost parts of the palaeovalley, while elsewhere it is confined to a 20 m wide and 2 m deep gully in the bottom of palaeovalley.

2.3. The Organic and tufa facies

The second phase in the infilling of the palaeovalley is represented by the Organic and tufa facies. The organic material, varying from wood peat above clayey-peat to peaty-clay with many wood fragments, is the dominant component. The Tufa component, consisting of fine to coarse grained calcium carbonate, occurs in lenses of varying shape and dimensions, incorporated in the organic material. The position of these lenses may change considerably from one location to another; they can appear either at the top or near the bottom of the peat layer, in the centre of the valley or nearer the flank. At locations where smaller affluents join the main river, the tufa lenses may be particularly abundant.

In the centre of the palaeovalley where it overlies the Gully facies, the Organic and tufa facies may be 2 to 3 m thick, and in exceptional cases, 5 m thick. It gradually thins towards and up the valley walls, where it rests directly upon Pleniglacial fluvial sand. At locations where valley walls are rather steep, it wedges very suddenly; elsewhere slopes are more gentle and the sediment unit wedges more gently.

The boundary between the Gully facies and the Organic and tufa facies generally coincides with a sudden widening of the palaeovalley. This is especially true in the case of a flat palaeovalley bottom with a narrow gully (Fig. 3c). Although the Organic and tufa facies always contains a certain amount of clastic material, it can be considered as relatively pure in the downstream area. Upstream however, intrusions of important clastic bodies appear more frequently. When the valley gradient becomes even higher, the Organic and tufa facies may disappear completely, and in the upstream areas only relicts can be identified.

2.4. The Fluvial clay facies

The Fluvial clay facies consists of green and grey soft fluvial clay with plant debris and vivianite. Organic debris, wood fragments and peaty horizons may occur. Sandy layers may occur but they are thin and dispersed in the vast clay body. However, at some locations, the sands are more abundant and attain a considerable thickness. These are relicts of river channels (Huybrechts, 1989). The Fluvial clay facies can reach a thickness of 5 m, but generally fluctuates between 2 and 3 m. It represents the last phase of the infilling of the palaeovalley. Its lateral extension corresponds with the maximum dimensions of the palaeovalley.

2.5. The Surface loam facies

The Surface loam facies consists of brown and greyish-brown silty sediments, varying from sand-loam to clay. The present-day floodplain topography has developed in this sediment unit. The granulometric characteristics vary according to the distance to the present-day river bed: coarse on the natural levees and fine in the flood basins.

3. Genesis and age of the flood-plain sediments

The sedimentological units of the post-Pleniglacial floodplain deposits can be relatively easily recognised in the field, and they occupy a stable stratigraphical position. This is especially true in the downstream parts of the floodplain. Due to higher energy conditions in upstream reaches, disturbances are more likely to occur. The presence of the Organic and tufa facies greatly facilitates the identification and dating of the various sediment units, and the reconstruction of the environmental conditions at the time of their deposition.

The accumulation of organic material depends on specific conditions, where production of organic debris can occur, although its decomposition is slow. High water tables ensure that the soil is permanently saturated so that the decomposition of organic debris is reduced. On the other hand, a water table that leads to permanent inundation would hamper the development of vegetation and the production of organic debris. In high energetic conditions (e.g. close to the river), organic debris is reworked and oxidisation is enhanced (Stone and Gleason, 1981). The accumulation of organic material thus depends, to a large extent, on local hydrological conditions.

The age of the lithological units is based on radiocarbon dating of mainly the Organic and tufa facies. A large number of radiocarbon datings are required in order to understand possible variations in age that are related to local hydrological conditions. In the Mark catchment, 37 radiocarbon datings were carried out in order to review the major longitudinal and lateral variations (Huybrechts, 1989).

The floodplain sediments were deposited after the erosion of the palaeovalley system, which was formed during the climatic transition from Pleniglacial to Late Glacial (Cleveringa *et al.*, 1988; Huybrechts, 1989). This same period of intense fluvial erosion was observed in many other river basins in Belgium (Mullenders and Gullentops, 1956; Verbruggen, 1971; Tavernier and De Moor, 1974; Haesaerts, 1984). However, no precise date for the beginning of this erosional phase could be established, and no information is available concerning the duration of this period, as datings are always obtained from fill deposits.

In the Mark river floodplain, it could be established that the erosion ended before 12,100 BP (Huybrechts, 1989). At that moment, the development of the floodplain sediments had started with the deposition of the Gully facies. This unit reflects the gradual reduction of the fluvial activity after the intense erosion phase. In the upstream parts, river activity prevented sedimentation for at least another 2000 years. Clear evidence for a reactivation of erosion during the Younger Dryas, as was observed in several other basins (Van der Hammen and Wymstra 1971; Verbruggen 1971; De Smedt, 1973; De Gans, 1981), is not available.

The sedimentation of the Gully facies ended with the start of the accumulation of organic and tufa deposits. Due to the development of 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. The effect of this evolution is particularly evident in the downstream area, where radiocarbon datings for the beginning of the organic accumulation cluster around 9000 BP. Because of the impact of the local hydrological conditions, such as the relationship between river activity and dimensions and form of the floodplain, deviations from the 9000 BP date can be expected.

In the upstream areas, where river slope was higher, the Gully facies developed poorly, and at some locations was not evident at all. The river continued to dominate its floodplain and reworked the fill deposits. The base of the Organic and tufa facies often coincides with a drastic widening of the palaeovalley. After filling, the narrow lowermost part the river suddenly occupies a very wide floodplain, and possibilities for the accumulation of organic debris improve. This may happen at any time.

Laterally in the valley, the start of the accumulation of organic matter may be delayed. Higher on the valley walls, drier conditions were initially dominant, thus preventing any organic accumulation. The accumulation started when these sites became wetter (between 9000 and 3000 BP).

From 9000 BP onwards, very stable conditions dominated major parts of the contemporary floodplain which was occupied by a marsh-forest. The transport of suspended material by the river was reduced and nearly all these sediments were deposited upstream, where larger clastic bodies are incorporated in the organic deposits. The floodplains were fed by large amounts of groundwater that supplied dissolved carbonates. After precipitation of the carbonates due to the loss of CO_2 from the groundwater (Gullentops and Mullenders, 1971; Marker, 1973; Terlecky, 1974), particles were transported by the river further downstream where they could settle, forming lenses of tufa incorporated in the organic material. For more than 3000 years (9000 to 6000 BP) this situation did not change significantly. The build-up of the floodplain, and the rise of the water table occurred at the same rate so that a thick peat layer with inclusions of tufa was formed (Visscher, 1942; Reineck and Singh, 1973; Baeteman, 1981).

At a certain moment, the simultaneous rise of the ground surface level and the water level was disturbed, which led to the deposition of the Fluvial clay facies. Radiocarbon dating reveals that the transition from organic facies to the clay facies does not correspond with a particular moment in the development of the floodplain, but the timing differs, mainly depending on the palaeomorphological conditions. The process started in the centre of the palaeovalley around 6000 BP. It was earlier argued (Huybrechts, 1989) that from 6000 BP onwards, in certain parts of the floodplain, the water level rose above topographical level. As a result of the stable water regime, it remained high all year, and an open water situation was created that replaced the marsh forests. In the course of time, the open water area increased, pushing the marsh forests to the side of the valley, before finally completely dominating the floodplain. Due to this process, the replacement of the Organic and tufa facies by the Fluvial clay facies occurs later in time as one proceeds from the centre of the palaeovalley to the sides. Dates ranging from 6000 BP in the centre, to 2500 BP more laterally, were obtained. The contribution of groundwater to the floodplain diminished and was replaced by surface run off, thus reducing the supply of carbonates and the formation of tufa.

It has been earlier argued that Neolithic man was responsible for these changes in the sedimentary processes in the floodplain (Mullenders *et al.*, 1966; de Heinzelin *et al.*, 1977; Froehlich *et al.*, 1977; Paulissen *et al.*, 1981; Huybrechts, 1989). Scattered and rather limited deforestations by Neolithic man for agricultural purposes could have led to increased run off and erosion in the basin, resulting in higher water levels in the floodplain and the deposition of fluvial clay.

The deposition of the Fluvial clay facies continued until at least 1400 BP. Shortly after this date, the palaeovalley system was completely filled, and by then was no longer visible in the alluvial landscape. The Surface loam facies was deposited independently of the palaeovalley system, covers the entire floodplain, and is related to the present-day position of the river. The Surface loam facies was deposited during high winter floods, when the Mark River inundated its floodplain, as was earlier suggested (Galeotti, 1837; Cornet, 1909; Tavernier, 1947; Gullentops, 1957; Mullenders *et al.,* 1966; De Smedt, 1973; Paulissen, 1973). Unlike the Fluvial clay facies, where a stable regime reigned to provide a permanent high water level, the Surface loam facies is related to an unstable regime with high winter 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.

4. Conclusions

The post-Pleniglacial sediments in floodplains of medium-size rivers in the western part of Central Belgium consist of four lithological units: the Gully facies, the Organic and tufa facies, the Fluvial clay facies and the Surface loam facies. Three of these units are confined to the palaeovalley system, that dominated the floodplain landscape for more than 10,000 years. During this long period, the floodplain was much smaller than the present-day floodplain. Fluvial activity was limited to the palaeovalley. Only the uppermost Surface loam facies has been formed independent of the palaeovalley system (Fig. 4).

Floodplain sediments reflect the hydrological and sedimentological conditions and the changes that occurred in the floodplain and drainage basin during the last 12,000 years. This evolution is controlled by climatic changes and human activity in the catchment. The local conditions in the floodplain such as cross-sectional profile, longitudinal profile, the width of the floodplain etc. also influence the sedimentological processes to a certain extent, especially with regard to the timing of the lithological changes and their spatial distribution.

The formation of the palaeovalley system, more than 12,000 years ago, results from hydrological instability related to the transition from glacial to post-glacial climate. The Gully facies reflects the gradual recovery from this instability, which culminated in the formation the Organic and tufa facies. From approximately 9000 BP, a stable landscape existed with limited catchment erosion and fluvial activity, and a high contribution of groundwater to the floodplain.

A second landscape instability was induced by human activity as early as 6000 BP. By affecting part of the vegetation for agricultural purposes, the sediment and water yield of the catchment increased. This resulted in permanently high water levels in the floodplain and the deposition of the Fluvial clay facies. Eventually, the marsh forest disappeared from the floodplain. This evolution culminated in medieval times, when the deforestation affected the river regime that became irregular with high winter and low summer discharges. This resulted in the deposition of the Surface loam facies.

A fourfold construction of the post-Pleniglacial floodplain sediments has been identified in only one other catchment (Diriken, 1982). This is not surprising since the Gully facies occupies the bottom of the palaeovalley and has limited lateral development, which can only be established by means of a large number of borings to a greater depth. In some other floodplains of small-to-medium size catchments, sediment units have been identified that have lithological characteristics and a stratigraphical position comparable with the Organic and tufa facies, the Fluvial clay facies and the Surface loam facies (Mullenders and Gullentops, 1956; Mullenders *et al.*, 1966; De Smedt, 1973; Haesaerts and de Heinzelin, 1979).

However, in floodplains of larger rivers and in different geographical regions, many aspects of the architecture of the post-Pleniglacial floodplain sediments differ from the results obtained in the Mark catchment (Munaut and Paulissen, 1973; Paulissen, 1973; Kiden,

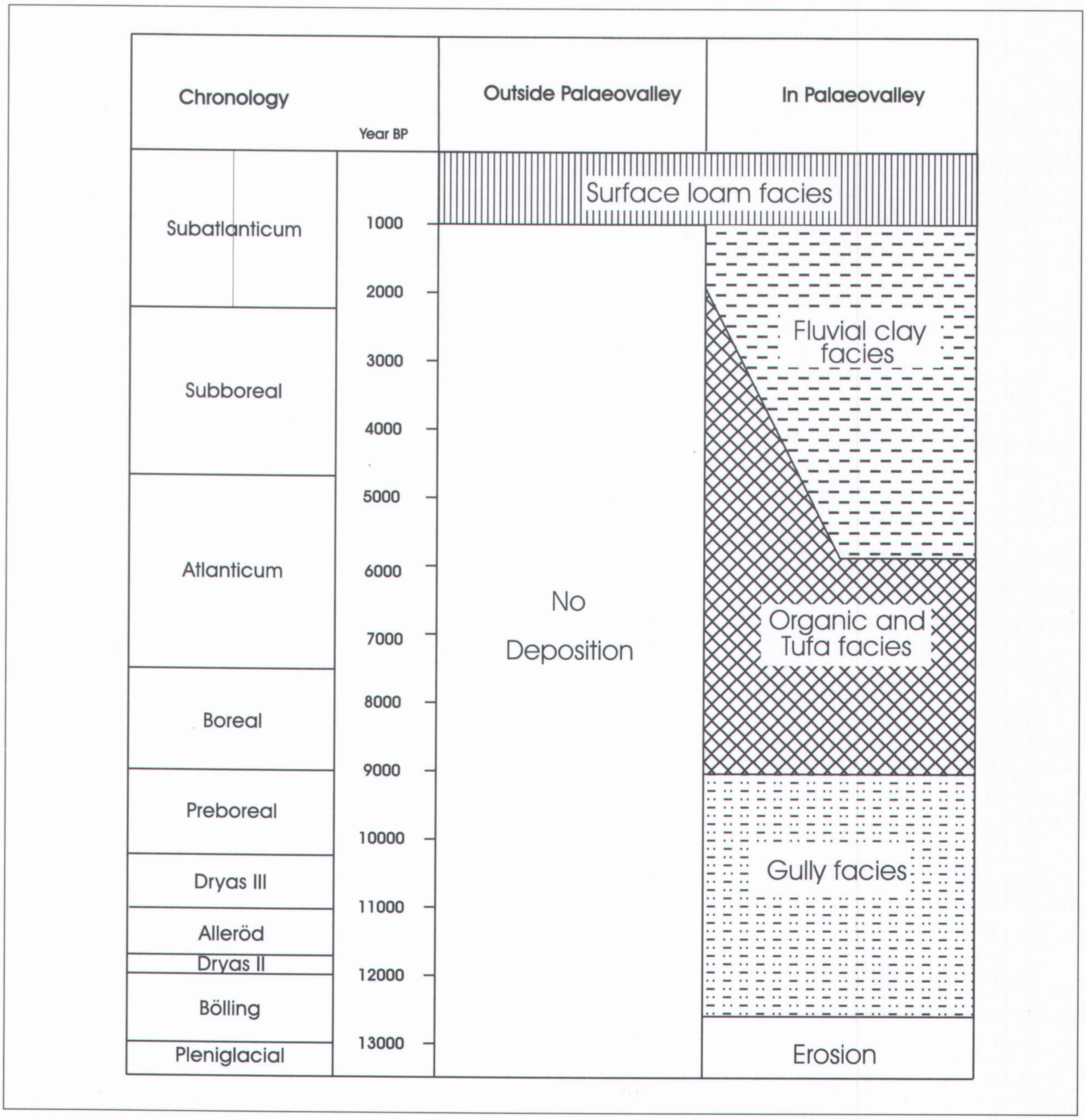

Figure 4. Stratigraphical table.

1991; De Smedt, 1973). These rivers clearly exhibit different hydrologic responses to changes in external factors, i.e. with regard to the Late Glacial erosion phase, as well as the subsequent sedimentation phases. A general stratigraphy of post-Pleniglacial floodplain sediments should take this geographical variation into consideration.

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