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Saalian nivation activity in the Bosbeek valley, NE Belgium

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Abstract

The geomorphological analysis of the Bosbeek valley, situated in the present-day temperate climate of Belgium, establishes that in the Saalian periglacial environment snow played a major role in shaping the landscape. It is inferred that snow banks were important for a rapid and considerable retreat of the western valley side in loose deposits. Intense snowmelt in the beginning of the short summers was responsible for the formation of a periglacial pediment between the valley side and the river floodplain. By these processes the Saalian was, at least in northeastern Belgium, the most effective glacial stage in terms of erosion. During the Weichselian, the Saalian periglacial landscape was only slightly remodelled by river incision and cover sand deposition.

Introduction

The Bosbeek valley forms the major drainage line in the Kempen (= Campine) Fan-Plateau in northeastern Belgium (5°35′–5°42°E, 51°00′–51°15′N; Fig. 1). This plateau is a remnant of a complex alluvial fan, deposited by the rivers Rhine and Maas (= Meuse), which consists of seven to twelve metres of coarse sand and gravel. The ultimate deposition is represented by Elsterian fluvioglacial deposits of the Maas (Zutendaal Gravel; Paulissen 1973). Shortly after this deposition, tectonic uplift induced considerable incision by the Maas of its fan and the underlying Miocene sands. The Bosbeek, a tributary of the Maas, that originates on the fan, follows the main valley formed during this incision.

The course of the Bosbeek is SW-NE, slightly oblique to the general northern dip of the fan-plateau and perpendicular to the northeastern plateau rim, which is the escarpment of the Feldbiss Fault system. The valley has a length of 14 km, a mean slope of 2.34 m/km and a maximum incision of 35 m. Its drainage basin is about 75 km^2 of which about 17 km^2 occupy the valley floor. Figure 1 shows the geomorphological features of the valley.

Asymmetry of the drainage pattern

The drainage pattern of the Bosbeek basin is asymmetrical (Fig. 1). The numerous righthand tributaries are short, have a perpendicular confluence and are normally dry. The few lefthand tributaries are longer and have an oblique confluence. They are permanent brooks, fed by springs and seepages. These differences can be explained by the interaction of valley erosion and water table lowering (Fig. 2). After the tectonic uplift, the Bosbeek was not able to follow the rapid erosion of the Maas. This effect was enhanced by the lowering of the water table by the Maas (De Smedt 1977).

On the interfluve between Maas and Bosbeek, the lowering of the water table was most drastic. Deep asymmetric valleys developed, essentially during Saalian periglacial conditions (Gullentops & Paulissen 1972). At the margins of the Maas valley,

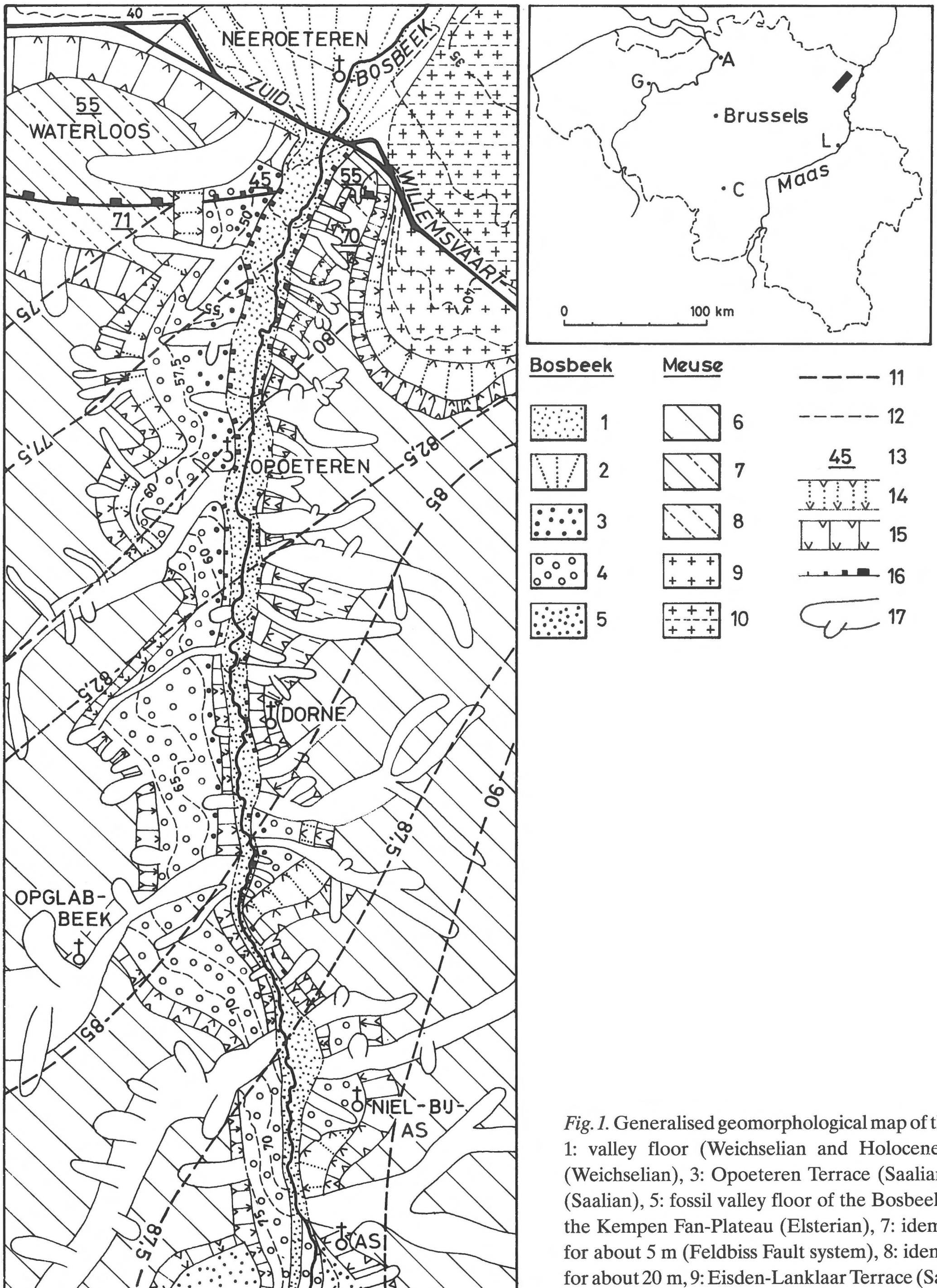

Fig. 1. Generalised geomorphological map of the Bosbeek valley. 1: valley floor (Weichselian and Holocene), 2: alluvial fan (Weichselian), 3: Opoeteren Terrace (Saalian), 4: valley glacis (Saalian), 5: fossil valley floor of the Bosbeek, 6: fan gravels of the Kempen Fan-Plateau (Elsterian), 7: idem but downfaulted for about 5 m (Feldbiss Fault system), 8: idem but downfaulted for about 20 m, 9: Eisden-Lanklaar Terrace (Saalian), 10: Mechelen-aan-de-Maas Terrace (Weichselian), 11: generalised contours (every 2.5 m) on top of the Kempen Fan-Plateau, 12: detailed contours in the Bosbeek valley, 13: spot height, 14: slopes with important Weichselian aeolian accumulation, 15: slopes, 16: escarpments with heights from left to right < 2 m, 2–4 m, 4–8 m and > 8 m, 17: tributary valleys.

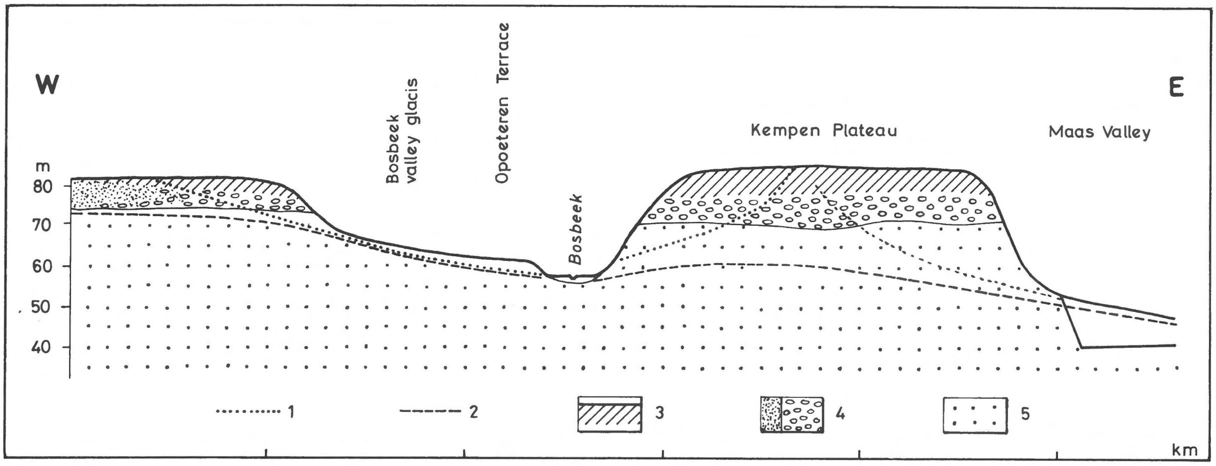

Fig. 2. Schematic W-E transverse profile from the Bosbeek valley towards the Maas valley between Opoeteren and Opglabbeek. 1: longitudinal profile of tributaries, 2: present-day ground-water table, 3: As Palaeosol (post-Elsterian), 4: gravels and sands of the Kempen Fan, 5: Miocene sands.

the incision of tributaries was favoured by seepage of ground water, while tributaries along the Bosbeek valley quickly became dry and were hampered in their development (Fig. 2). The lowering of the water table allowed the formation of a deep palaeosol, the As Palaeosol, during pre-Saalian interglacial conditions.

Under the extensive western part of the fan-plateau, west of the Bosbeek, the water table was lowered less deeply and the lefthand tributaries were elongated by regressive erosion. Their headwaters were redirected to the west in accordance with the water table gradient. The higher water table in this western part hampered the development of the As Palaeosol and maintained the sandy gravels in a less cohesive condition.

Asymmetry of the valley sides

The 35 m-high eastern valley side, the slope of which reaches 35% in the upper cohesive gravel layer, is closely parallel to the rather rectilinear Bosbeek course. The western valley side, on the contrary, consists of four large bends which are situated about 1.5 km from the valley centre (Fig. 1). Their backslopes are about 10 m high and up to 20% steep. The lower height and steepness of the western slope are partly due to the accumulation of windblown cover sands at the foot of the slope during the dry final phase of the Weichselian (Brabantian). It is evident that the bends in the western valley side are not due to lateral erosion by the straight Bosbeek. In addition, the bends are unrelated to the position of small tributaries and independent of their erosion. As they do not coincide with the tributaries, spring-line regression can be excluded as a major cause. Therefore, it is most likely that they have been generated by slope regression. Slope retreat must have been accompanied by the evacuation of huge debris masses of which coarse gravels were an important part. It is suggested that nivation activity associated with snowbanks fulfills these conditions.

The western valley side, exposed to the southeast, formed originally the first leeward depression on the flat fan-plateau which extends 30 km to the northwest. In periglacial conditions, snow could have been driven by western to northern winds over this surface and accumulated in this depression. This snow accumulation may have been many times larger than the normal local precipitation. Long-lasting snowmelt in summer will have increased 1) active-layer processes, accelerating slope retreat, 2) the effect of frost cycles, breaking up the cobbles to more transportable dimensions and 3) the amount of melt water, capable of evacuating the debris from the nivation benches. The configuration of the bends would have given them a high nivation activity, combining high snow reception with little insolation. Furthermore, seepages which add to the soil saturation and the melting of icings will have increased the nivation effects. The lower resistance to erosion of the Kempen Fan on the western side of the Bosbeek should have been instrumental as well in the accelerated retreat of the benches. This lower resistance is attributed to the westward increase of sand in the Kempen Fan, to the thinning of the Zutendaal Gravel and to the less developed As Palaeosol.

The importance of nivation benches was conclusively demonstrated by St-Onge (1965) in contemporary periglacial conditions. However, in fossil environments they have rarely been recognised. Gullentops et al. (1966b) described nivation benches on the Ardennes Plateau above 400 m altitude. The occurrence of nivation benches at 80 m in the study area, indicates that a large, flat, snowdrift source area may have compensated the smaller amount of snow precipitation.

Valley floor

The Bosbeek flows in a flat, practically straight, valley floor, with a length of 14 km and an area of 3.8 km^2. This floor gradually broadens downstream to a width of 450 m. It is incised in the valley glacis (Fig. 1; see below) with a maximum incision of about 5 m. The floor is composed of a thin (0.5–1 m) sandy gravel sheet, overlying Miocene sands and covered by up to 2 m of Weichselian cover sands. This Weichselian level is only slightly incised by the present brook and thus can be considered as the actual flood plain. Downstream of the Feldbiss Fault scarp (south of Waterloos, Fig. 1), this level grades into an alluvial fan that accumulated in the Central Graben where it interfingers with Weichselian Maas deposits of the Mechelen Terrace (Paulissen 1973). This indicates that the Bosbeek valley floor was formed during the early wet phase of the last glacial.

Bosbeek valley glacis

Between the valley floor and the steep upper valley sides a gently sloping surface is found with an area of 13 km^2 (Fig. 1: valley glacis). More than 80% of this surface is situated in the west of the asymmetrical valley (Fig. 2). It has a gentle, concave, transverse profile, rising from 1% to 3 or 5%, with a smooth transition to the steeper valley sides. Its width ranges from 300 to 1200 m in the nivation bends. It can be described as a valley glacis, i.e. a slightly dipping ablation surface.

In a number of excavations the Miocene sands are covered by a thin sheet (0.5–1 m) consisting of an alternation of discontinuous sand, sandy gravel and gravel layers deposited by turbulent shallow water. Cobbles larger than 6.4 cm are exceptional. Downstream, the glacis grades into a flat surface. The gravel here is up to 2 m thick, contains less sand and is deposited in well-sorted, thin beds. Its mean grainsize is 2 cm and cobbles are rare. The morphology and sediments justify the gravel's designation as the Opoeteren Terrace. The top of the gravel is weathered into a homogenised and reddish brown palaeosol of interglacial origin (Eemian), first described by Deckers & Baeyens (1963). The terrace, the palaeosol and the glacis are fossilised by the overlying Weichselian cover sands which thicken towards the concave valley sides. The present-day tributaries, which grade towards the Weichselian valley floor, form visible drainage paths with a downstream incision in the glacis.

Origin of the glacis

The formation of the glacis is related to the retreat of the nivation backslopes. As this retreat went on, the glacis was simultaneously lowered and graded towards the synchronous valley floor, the present-day Opoeteren Terrace (Fig. 2). Debris from the retreating valley sides were transported over the glacis. The processes responsible for this erosion and transport are documented by the correlative sediments.

Erosion surfaces on fine sands are well developed in the Kempen and they were described by Gullentops et al. (1966) as periglacial pediments. This term was introduced by St-Onge (1965) to describe the present-day planation of the Beaufort

Sands in the periglacial environment of Ellef Ringness, Canada.

The sediments of the Bosbeek glacis show deposition in turbulent flow capable of transporting sands and pebbles. Longitudinal southwest-northeast transport over the whole surface would need a large braided river. However, a discontinuous downslope transport system, as is active on a typical pediment, is proposed. Water gathered from areal runoff is assumed to reach erosional strength in short collecting branches and to deposit its load in small fans, eventually producing sandy foresets. Unimpeded runoff demands a scarce vegetation such as prevails in semi-arid climates or severe tundra conditions. A southern shrub tundra is considered as too dense a vegetation. Only a herb tundra with a phyto-mass of about 1 t/ha (Walter 1973) would do. Similar sediments of a Weichselian periglacial pediment at Ramsel in northern Belgium (Gullentops et al. 1981) contain a flora characterised by creeping willow, *Armeria,* some Cyperaceae and numerous water plants (L. Huysmans, pers. comm.). It is suggested that in the periglacial middle latitudes the required scarce vegetation is not determined essentially by low summer temperatures, but by a short growing season due to a long-lasting snow cover (Gullentops 1977).

The transport of sediment on the glacis demanded high discharges which were possibly favoured by a number of factors. It is estimated that more than half of the precipitation was snow which melted in a short period at the beginning of the summer season. According to St-Onge (1962, 1965) such snowmelt runoff has a daily rhythm with a maximum at the end of the afternoon. Occasionally, these maxima are increased by warm winds or rain. St-Onge (1962, 1965) and Cook (1967) were the first to stress the importance of the resulting peak discharges, even in the snow-poor Canadian Arctic. In our case, with an assumed thick snow cover (more than 1 m in the humid anaglacial phases), the snowmelt runoff was mostly subnival. On a frozen soil, surface erosion should be hampered considerably. It is thought, however, that in these humid phases conditions were more comparable to modern alpine environments than to modern arctic situations (Gullentops 1977). Early snow may have fallen on a not yet frozen soil and insulated it from (deep) frost penetration. Subnival runoff would then have had much more effect. Moreover, the amount of snow would have been increased by the snowdrift, which accumulated in snowbanks in the nivation bends, increasing the runoff and its duration. The runoff percentage would have been high because there was no appreciable loss either through evapotranspiration or through infiltration. An eventually frozen soil might have hampered infiltration and it should be recalled (French 1976: 142) that the thawing of pore ice and segregated ice lenses in the active layer can be an important element in the water balance. In the case of unfrozen soil, however, the high water table could have caused water-saturated conditions in which sediment fluidisation considerably facilitated erosion. Later summer rains on snow-free ground caused supplementary runoff, even taking into account that progressive drying of the soil led to infiltration loss. We cannot follow De Ploey (1972) in his conclusion that this rainwash was the essential process.

The evacuation of the fan-plateau gravels required intense frost activity. Indeed, the gravels of the Maas fan contain a considerable amount of boulders, many of them larger than 30 cm. Boulders of this size are found only rarely in the gravel sheet of the glacis and in the Opoeteren Terrace. As the evacuating power of the pediment system and of the Bosbeek was certainly smaller than the transport capacity of the Maas, we might expect to find the boulders as a residual deposit on the glacis. Even a lag layer might have been formed, thick enough to stop further erosion. As this is not the case, it is inferred that frost splitting in the nivation benches continued on the soaked pediment until the transport capacity was reached.

It is included that the glacis was formed under seasonally cold but also humid conditions, with much snow and many freeze-thaw cycles. It developed by runoff, essentially fed from snowmelt, and extended asymmetrically through regression of nivation backslopes. The term periglacial pedimentation properly describes the complex of processes and conditions. The term cryoplanation (Bryan 1946) does not apply because it emphasises frost activity as the major cause instead of meltwater runoff.

Age of the periglacial pediment

The glacis grades laterally towards the Opoeteren Terrace. The latter is covered by an interglacial palaeosol and Weichselian cover sands and is incised by the Weichselian valley floor. Therefore, the periglacial pediment and the nivation backslopes must have been formed during a pre-Weichselian glaciation. After the formation of the Kempen Fan-Plateau (Elsterian), but before the formation of the palaeosol, at least three glacial stages occurred. Of these, the Saalian has the coldest climate as is indicated by its push moraines 100 km northeast of the study area. Furthermore, the Saalian terraces are the most important ones in the Maas valley (Paulissen 1973). In addition, a Saalian age was found for the nivation activity in the Ardennes (Gullentops et al. 1966a) and for the intense erosion which formed the present-day dry valleys of the Eastern Kempen Plateau border (Gullentops & Paulissen 1972). All this stresses the importance of the Saalian periglacial environment in the non-glaciated area between the Scandinavian and Alpine ice masses.

It is possible that nivation activity was already initiated in previous glacial stages, but that its effects were wiped out in the Saalian time. During the Weichselian, pedimentation activity may have resumed for some time. However, this activity did not create the glacis, but only slightly re-shaped it, eroding essentially the present drainage paths. The modest Weichselian incision of the Bosbeek, by lowering the ground-water table, fossilised the glacis and indicates the weaker erosional impact during the last glacial stage.

Conclusion

The geomorphological analysis of the Bosbeek valley, located in the present-day temperate climate of Belgium, establishes that in the Saalian periglacial environment snow played a major role in the morphological development of the landscape. Nivation banks were responsible for the rapid and considerable retreat of the southeast-facing valley side in loose deposits. Rapid snowmelt in the beginning of the short summers was important for the formation of a periglacial pediment between the western valley side and the Saalian river bed. Weichselian erosion only slightly re-shaped this pediment and finally fossilized it by a lowering of the water table.

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