

SOILS AND THEIR GEOLOGY IN THE GEUL VALLEY

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1. INTRODUCTION

The river Geul rises near Eynatten in Belgium. It enters The Netherlands near Cottessen and flows into the Meuse near Bunde. By then it has covered about 56 km, two-thirds of this distance being in The Netherlands (Fig. 1). From the Dutch-Belgian frontier to Mechelen it flows in a south-north direction, from Mechelen to Schin op Geul it runs north-west and from Schin op Geul to Bunde in a more westerly direction. It receives many small tributaries. Together they form an essential part of the pleasant South Limburg landscape (Fig. 2).

By Dutch standards the Geul is a fast flowing river. The slope varies from about 7.62 m/km near Epen to 1.33 m/km near Houthem. The average is about 3 m/km. Its discharge is very irregular. Near Meerssen the average discharge is

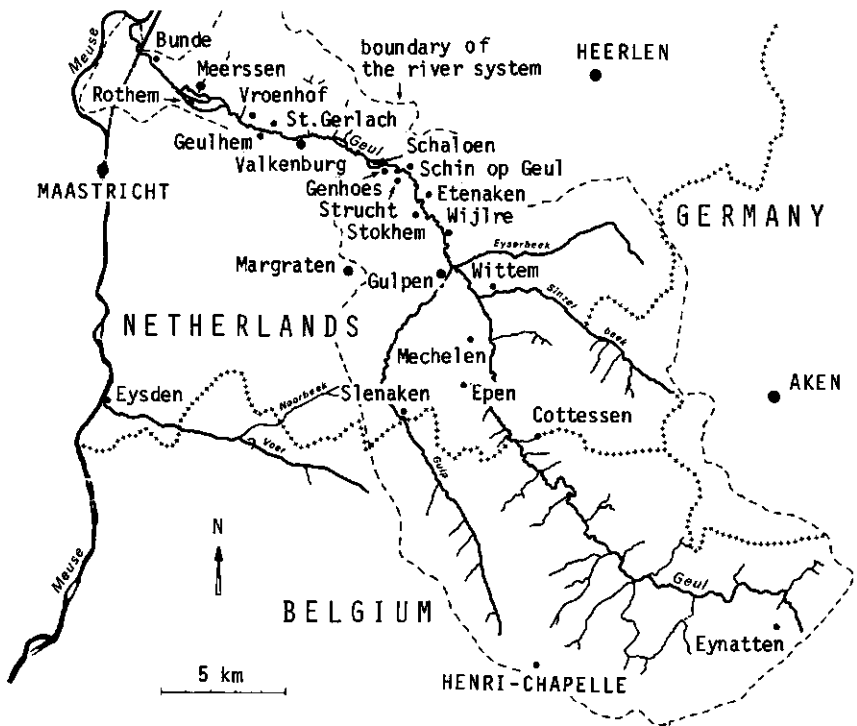


FIG. 1. The river system of the Geul.

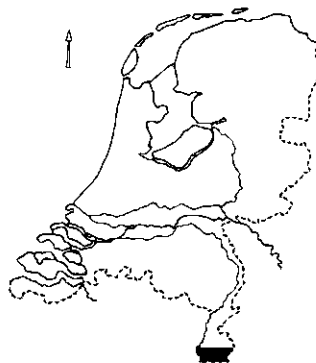




FIG. 2. The pleasant landscape of the Geul valley.

about 2,300 l/s; the minimum discharge in recent years was 950 l/s (September 1971), with a maximum of 24,200 l/s in October 1974. In the very wet period of December 1966 the discharge at Valkenburg was about 65,000 l/s (Information supplied by the Limburg Public Works Department).

Under present conditions severe flooding is relatively rare. The last flood was in the spring of 1974. On an average floods occur every two years. The discharge by means of regulation, has been improved so that floods can be prevented or their duration shortened. Locally small areas are more frequently flooded. When floods occur in the late autumn, winter or early spring, there is usually little damage to agriculture, high water levels being generally of short duration. Before the modern regulation of the Geul the river had a natural character. But it should be added that for centuries the water discharges and levels have been influenced by man, e.g. by land reclamation, the construction of watermills, etc.

The geology and soil conditions of the Geul valley also reflect agricultural practices in the South Limburg loess landscape.

2. GEOLOGY

Five different stages could be distinguished in the history of the valley fill in the Geul basin. The first stage is of pre-Holocene age, the other four are Holocene.

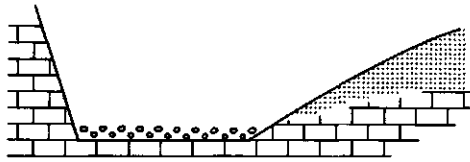
2.1. STAGE I (FIG. 3a)

The shape and the size of the Geul valley indicate a Pleistocene origin. During the formation of the dissected plateau landscape the valley of the Geul, a major tributary of the Meuse, was deepened and widened. As a result of various geological processes the cross section of the valley has become asymmetrical in many places, with one steep side and one gentle slope. Small terrace-like irregularities are occasionally found along the valley walls. At the end of the Pleistocene the dissected plateau landscape has been covered by aeolian loess.

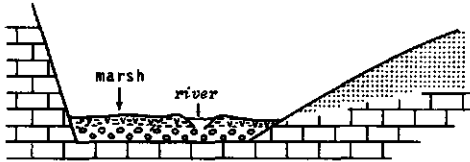
The valley was largely incised in Upper-Cretaceous limestones. In the flood plain of the present valley some metres of Pleistocene gravel were laid down by braided rivers overlying the Cretaceous material. Holocene sediments have been deposited on top of it. These last deposits give the valley its present character.

2.2. STAGE II (FIG. 3b)

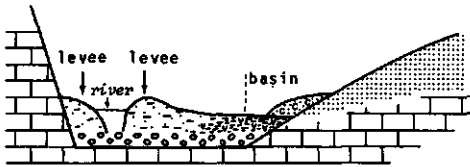
The temperature rose at the beginning of the Holocene and initiated a new, more thermophilic type of vegetation (JANSSEN, 1960). This led to a forest vegetation in the whole South Limburg loess area. The natural situation of the



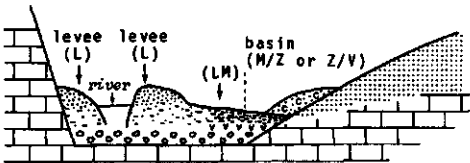
a. Stage I. Pleistocene; deposits of a braided river, gravel.












b. Stage II. Holocene; oldest deposits, clay and peat.

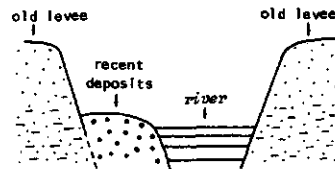


c. Stage III. Holocene; increased activity, fine-silty deposits.



d. Stage IV. Holocene; increased activity, coarser-silty deposits.

-  cretaceous limestone
-  aeolian loess
-  gravel
-  peat
-  clay
-  fluvial material, fine-silty
-  fluvial material, coarse-silty (loess-like)
-  colluvial material (loess-like)
-  fluvial material, sandy



e. Stage V. Holocene; recent deposits, sandy.

FIG. 3. Stages in the filling of the valley of the Geul.

Geul valley in wooded South Limburg was wetter than at present as a result of its low elevation with respect to the surrounding hills and the occurrence of springs along the valley at points where water rises over heavy, impermeable Lower-Cretaceous clay layers or flows in Cretaceous limestones. The vegetation became a marsh forest (HAVINGA and VAN DEN BERG VAN SAPAROE, 1980).

At the beginning of the Holocene, in such a densely forested landscape, the river mainly carried groundwater base flow that reached the valley through springs and seepages. In a wooded landscape when precipitation exceeds the evapotranspiration the surplus water does not reach the river via the surface, but

through the soil and after deep percolation via the groundwater. At this period the difference between base flow and peak discharge of the river was not great. As the landscape was covered by vegetation the suspended load of the river was small. There was little or no sedimentation. Only some clay was deposited, or else peat was formed.

2.3. STAGE III (FIG. 3c)

As long as the entire loess area was under permanent vegetation the discharge and activity of the Geul remained more or less unchanged. It was only slightly affected by climatic changes in the Holocene. The situation was again changed when the vegetation was cleared by man and bare soil became subject to erosion.

The first human settlers in South Limburg to clear some parts of the forest were the Dutch Bandkeramik people. They lived on the boundaries of the level loess plateaus. They were farmers and their arable land was on the plateaus. The coarse-silty top layers of the loess soils had a lower clay content than the fine-silty subsoils and were weakly acidic. This soil condition was conducive to arable farming, as sparse woodland was growing on loamy and weakly acidic soil (PONS, 1973). For reclamation and farming such situations were attractive because:

- it was relatively easy to clear the sparse woodland and reclaim the land,
- the original vegetation was easier to control than on clayey and rich soils,
- tillage of coarse-silty soils was easy.

Owing to the situation of the arable land on plateaus and the sparse forests around the fields on the boundaries of the plateaus and on the hills, the hydrological regime was only subject to slight change. Erosion was not serious and most of the surplus water still reached the river via the groundwater. In this part of South Limburg no settlements of Bandkeramik age have been found (BAKELS, 1978), so that little if any silt reached the river and the sedimentation rate was low. The sedimentation pattern in the Geul valley only differed slightly from the situation described in stage II. This was changed when larger parts of the loess area, both on the plateaus and on gentle slopes, were cleared by man. The natural vegetation disappeared and erosion started. It is not known whether erosion will have become serious as early as from the beginning of intensive agricultural practise or later on (at the end?).

It was during the Roman era that large parts of South Limburg were used for arable farming. The clearance of the natural vegetation and resulting erosion then had a marked effect on the regimes of the Geul and other rivers. It caused that the hydrological regime of the loess area was drastically changed and that the suspended load increased considerably. Up to this period the surplus water entered the soil and when the soil was saturated, the water percolated to the groundwater via which it eventually reached the river. But owing to the clearance of the vegetation in hilly areas less water penetrated the soil; instead it flowed laterally down the slopes. This meant that the surplus water took less time to

reach the river, and that the water levels and discharges became higher and more irregular with great differences between base flow and peak discharge. Owing to the greater discharges the current velocity, turbulence and sediment load of the river Geul increased substantially.

Soil particles eroded from the arable land to the lower parts of the landscape (colluvium) or to the rivers that deposited the material in the valleys (alluvium). Loess material, especially the coarse-silty top layers of the loess soils, is very liable to erosion. During heavy rainfall or thaw greater quantities of water and much silt of loess origin (i.e. with a high content of silt particles) entered the river. This was transported and deposited elsewhere.

The river's sedimentation pattern changed compared with that of stage II. Instead of clay and peat the river deposits now consisted of silty loess-like material, with a differentiation of texture from the levees to the basins. VAN DEN BROEK and VAN DER MAREL (1964) also refer to the loess origin of the fluvial soils of the Geul.

2.4. STAGE IV (FIG. 3d)

Later, when more vegetation had been cleared and more land was used for agriculture, esp. for arable, occasionally more water entered the rivers with greater frequency. As a result more water and silt flowed into the Geul; thus its current velocity and sediment load increased. It is the same process as described in stage III but more intensively. Our borings and the work of TEUNISSEN VAN MANEN (1958) clearly showed that most of the soils have a higher clay content in the subsoil than in the upper part of the soil. Apparently two important sedimentation stages should be distinguished. The latest stage must be the result of reclamations even more extensive than those which occurred in the Roman era (see above). It undoubtedly dates from the Middle Ages (HAVINGA and VAN DEN BERG VAN SAPAROE, 1980).

RIEZEBOS and SLOTBOOM (1978) also point to a relationship between soil erosion, sedimentation and human activity. In Luxemburg they found a change from peat to clayey material that could be dated to the 15th century. Although a climatic reason also might be an important factor, the use of land for farming, especially the increase of the arable/pasture ratio, caused an increased supply of sediment, combined with a rise in the water table or more frequent and extreme flooding by river water. This is in complete agreement with what was found in the Geul valley. The occurrence of many soils with a finer-silty subsoil may reflect a further deforestation or an increased arable/pasture ratio. The change from stage III to stage IV might be post-medieval.

According to BRUNNACKER (1977) about 1000 years ago distinct changes occurred in sedimentation patterns and soil conditions in the valleys owing to a substantial change in river movements. Although slight climatic changes and oscillations of the glaciers in the Alps and of sea level might have been of importance to large rivers, small rivers and brooks were mainly influenced by

human interference in the landscape. Deforestation led to erosion and the eroded material accumulated within the small valleys.

2.5. STAGE V (FIG. 3e)

After the Middle Ages the entire loess area was cleared and cultivated except for the steepest hills and poorest soils, where the forests remained. Forests still exist on sites where General Tranchot mapped forests in the beginning of the 19th century. This is a good illustration of the fact that large-scale reclamation has become impossible in recent centuries. Nor, of course did the rivers change their character during this period.

In recent times, farming practices have greatly improved (e.g. better weed control, row culture, reallotment). Otherwise this means that the arable land is exposed for longer periods, thus increasing erosion danger (BOLT et al., 1980). Another important factor is that in the 20th century many roads have been paved, so that overland flow increased. Moreover households use more water than before and all effluent water reaches the rivers through sewerage. These two non-agricultural causes may be the chief factors creating the irregular discharge of the Geul.

The net result is that the Geul sometimes receives more water than before. There is a possibility, however, that a different hydrological regime of the Meuse in former times also influenced the slope and current velocity of the Geul. Under present conditions the river cuts into its former deposits and the recent deposits are at a lower level. It is not the silt but the sand fraction that predominates in the grain-size distribution. Small, distinct terraces are formed (Fig. 4). The sands contain carbonates and are intercalated with organic matter. The

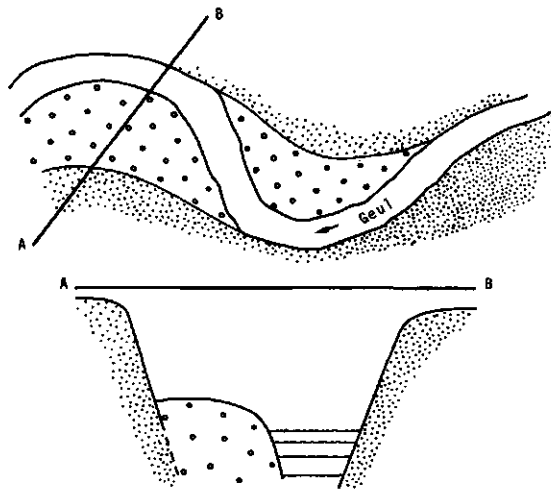


FIG. 4. Formation of small terraces and sandy deposits in recent times (cf. Fig. 3e).

present stream has cut so deeply into its own deposits that the river channel has cut into the Pleistocene substratum of the braided river. Its current velocity is not so great that it has cut into Pleistocene coarse gravel bed. Most of the material (clay and silt) that reaches the river flows to the mouth of the Geul and comes into the Meuse. The recent deposits in the valley are sandy and no longer loess-like.

3. SOIL CONDITION

3.1 SOILS

Most of the deposits in the Geul valley belong to stages III and IV, both in horizontal extent and in vertical depth or soil profile. As described in stages III and IV, the more recent loamy deposits of stage IV have a lower clay content than the loamy deposits of stage III. In many soils the texture trend increases with depth. TEUNISSEN VAN MANEN (1958), BRETELER (1967), DAMOISEAUX (1968) and VAN DE WESTERINCH (1979, 1980) record the same trend for the deposits of the Geul and its tributaries the Gulp and Eyserbeek. But a difference exists in the thickness of the coarse-silty part (e.g. texture L) overlying the fine-silty part (e.g. M) of the soil profiles.

In the Lower Rhine area in Germany it was also ascertained that the older Holocene river deposits have a finer texture than the younger river deposits. In contrast with the situation in the Geul valley several river terraces, all dating from the Holocene, are found at various levels in the Lower Rhine area (BRUNNACKER, 1978).

In general the more recent deposits of stage IV are thicker than the older ones. In the levee position the later stage is thicker than in the basin position. The texture of recent deposits also differs in the levee to basin direction; in the basin position the texture is finer.

Three classes of soil texture have been distinguished, viz. L, M and Z. These three classes record the clay content (lutum %) of the loamy (loess-like) parent material. They correspond to the soil textural classes of the SOIL TAXONOMY (1975):

L : approx. 10–20 % lutum ('coarse-silty')

M : approx. 20–30 % lutum ('fine-silty')

Z : approx. more than 30 % lutum

and V : peat or peaty material.

In general the levee soils have a textural class L over great depth, viz. exceeding 120 cm and sometimes 220 cm. Soils situated at the boundary between levee and basin have textural class L over M (coded LM), viz. within a depth of 120 cm the texture increases from L to M. Such soils show the two stages of geogenesis. An increasing textural trend was also found in many other situations. In the basin

positions soils are found with textures of M, MZ, Z or ZV. These not only indicate the basin positions but the two stages of geogenesis.

3.2. CALCAREOUS MATERIAL

Hitherto no reference has been made to calcareous material in the deposits of the Geul. As stated above, the river sedimentation had been correlated with the clearance of the vegetation and the reclamation of the loess area. When such activities led to soil erosion, loess-like material came into the river and was deposited. Hence sedimentation is a function of erosion and the carbonate content of deposits must be related to erosion.

The natural soil in the loess area covered by forest was a 'brik' soil (DE BAKKER and SCHELLING, 1966) or alfisol (SOIL TAXONOMY, 1975). Such a soil had no carbonates and was weakly acidic to a depth of 2.5 to 3.0 m. In other words, non-calcareous loess material was the first to erode.

The carbonate content of the deposits was determined by changes in the sources of eroded material and by the sedimentation pattern in the valley. Decalcification is another process affecting the carbonate content of the soils of the Geul valley. Further information on the carbonates in these soils has been provided by MIEDEMA (1980).

3.3. HYDROLOGY

The Dutch system of 'Gt' (= water-table classes) for characterizing the fluctuations of the groundwater is relatively unimportant for such a small valley as that of the Geul. The groundwater level in the valley largely depends on the height of the river water and this height may vary extensively. Mottling in the soils are evidences of the water fluctuations (reduction spots of a more grayish tint and brown or orange-brown oxidation spots).

The groundwater fluctuations of profiles with a deep homogeneous brown colour without mottles are characterized by a high Gt class (VII), i.e. the mean groundwater is always deeper than 1.20 m. Soils mottled at shallow depth but with a mean lowest groundwater table deeper than 1.20 m have wide groundwater fluctuations and are characterized by Gt V. Soils with higher groundwater levels (both the mean highest and the mean lowest) are characterized by Gt classes lower than V. They are mottled at shallower depth.

The simplified map of groundwater fluctuations in the Geul valley (Fig. 5) shows three main zones of Gt classes: a small zone with high Gt classes along the Geul, a transitional zone with Gt classes of wide groundwater fluctuations, and a zone with low Gt classes. The first zone corresponds to levees, the last to basins. Table I shows the Dutch system of water-table classes (Gt classes).

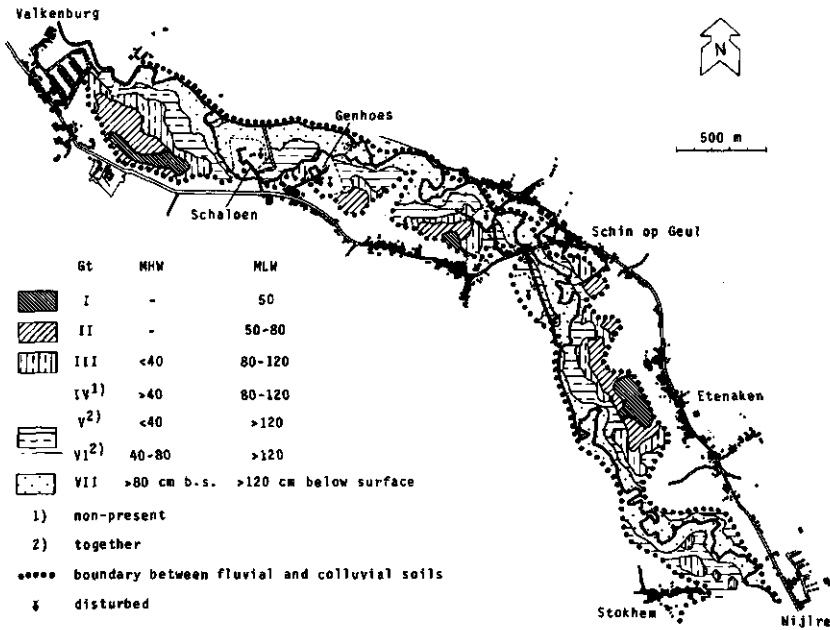


FIG. 5. Simplified estimated groundwater fluctuation ('Gt') map of the valley of the river Geul from Wijlre-Stokhem to Valkenburg.

TABLE I

Gt ¹	MHW ²	MLW ³	
I	-	< 50	
II	-	50-80	
III	< 40	80-120	
IV	> 40	80-120	
V	< 40	> 120	¹ Gt: water-table class
VI	40-80	> 120	² MHW: mean highest water table
VII	> 80	> 120	³ MLW: mean lowest water table
	(in cm below surface)		(cf. VAN HEESSEN, 1970)

3.4. SOIL MAP LEGEND

Three main classes have been distinguished in the texture of the fluvial soils in the Geul valley, viz. L, M and Z, indicating the lutum or clay percentage (= % < 2 micron), i.e. respectively ca 10-20%, ca 20-30% and more than 30% lutum (see 3.1). There is also a class V indicating organic matter contents of over ca 15% (peaty material and peat). Generally speaking, the texture of the soils is silt loam in which the clay content varies. It is derived from loess soils with a silt loam texture. Soil textures coarser than L, i.e. with less than 10% clay, only occur in

the most recent deposits. These have a sandy texture instead of a loamy one. As these deposits cover so small an area they could not be shown on the soil map.

The map units (Fig. 6) indicate the soil textural classes and combinations of classes to a depth of 120 cm of the soils. Figure 7 shows the texture profiles to a depth of 220 cm of some parts of the Geul valley downstream from Valkenburg. Although a change in textural class is shown on the field maps by means of numerals indicating its beginning (e.g. 1, 2, 3, 4, 5 and 6 respectively denoting its beginning up to 40 cm, from 40 to 80 cm, from 80 to 120 cm, from 120 to 160 cm, from 160 to 200 cm and from 200 to 220 cm), these numerals had to be omitted from Figure 6 because of the scale.

3.5. SOIL MAP

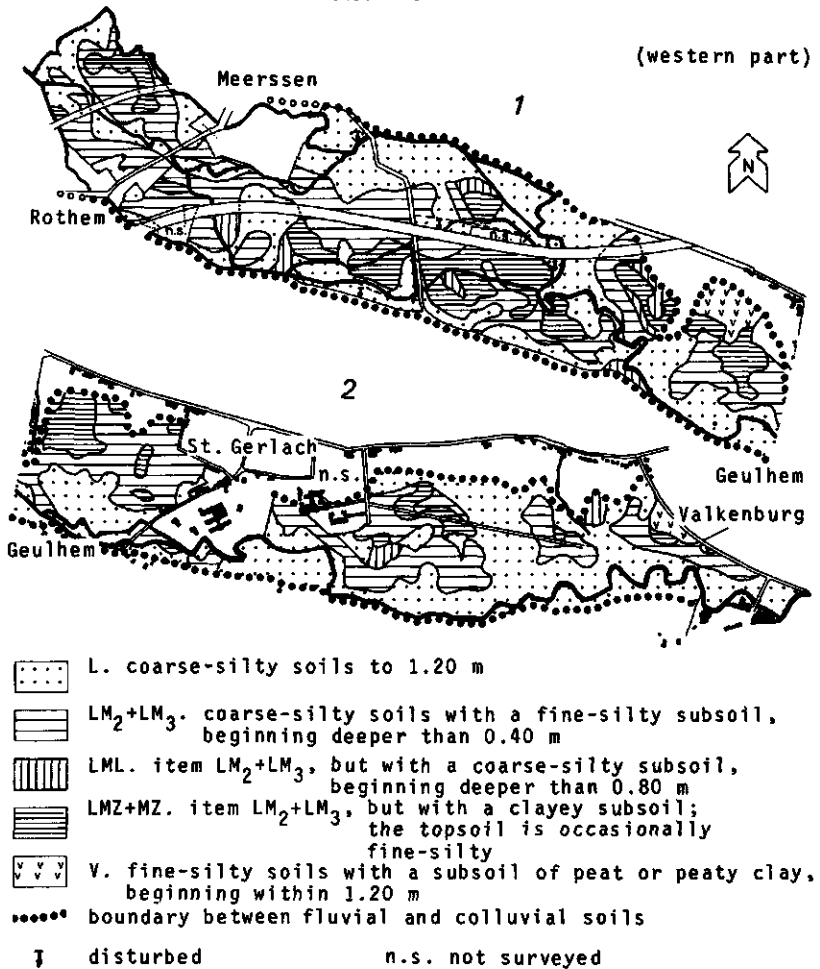
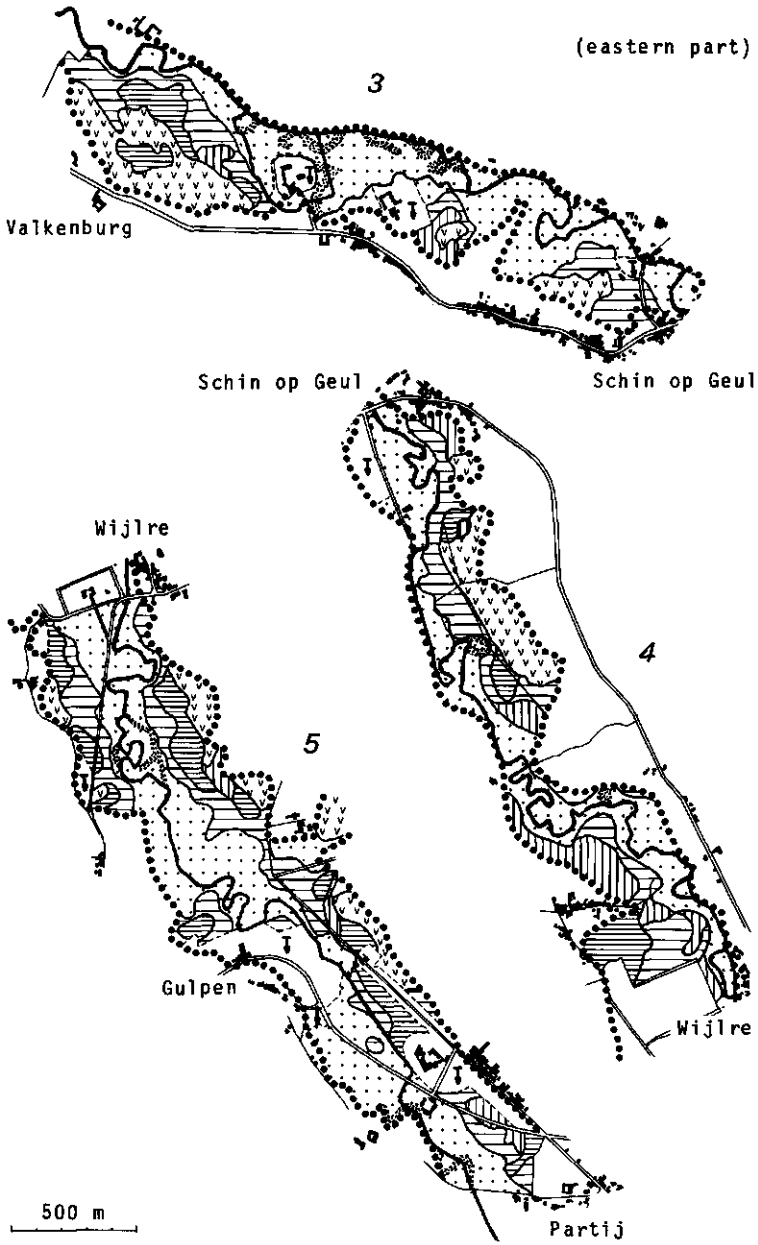


FIG. 6. Simplified soil map to 1.20 m of the Geul valley from Gulpen to Meerssen.



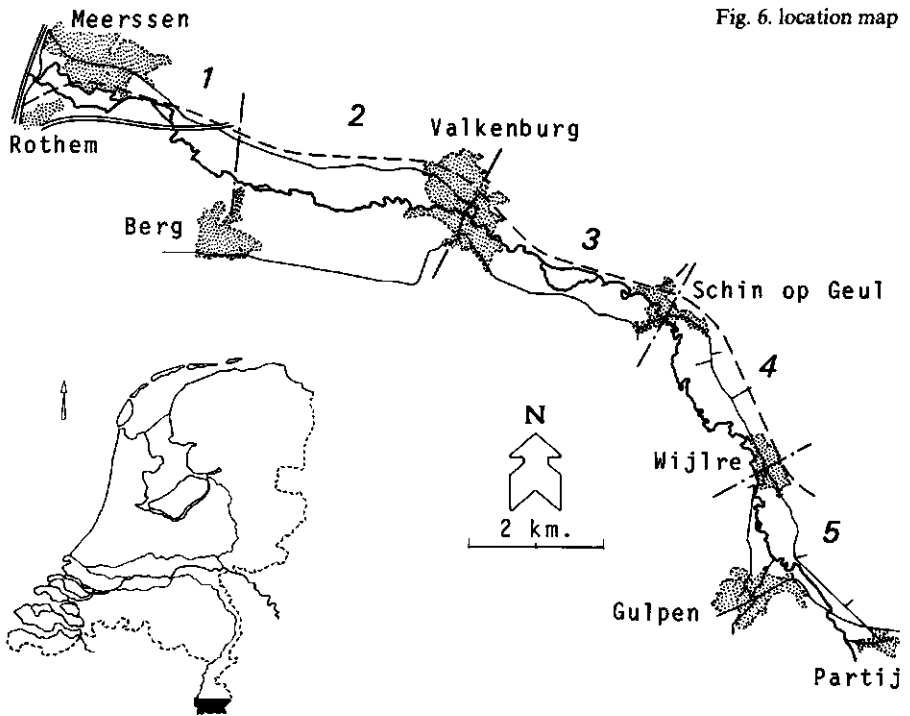


Fig. 6. location map

Figure 6 shows the soil map of the Geul valley from Gulpen to Meerssen, (borings to 120 cm). Figure 7 presents the soil map, based on borings to 220 cm, for part of the valley downstream from Valkenburg. Some general information is given first. Soils in the Geul valley with a level or nearly level surface are regarded as fluvial soils. Soils at the boundary of the valley beneath slopes, and at a higher level than the surrounding fluvial soils, are regarded as colluvial soils. As both fluvial and colluvial soils consist of loess-like material it is difficult to differentiate them. Where the Geul has deposited fluvial material the valley is narrow, varying from about 150 m near Etenaken and Strucht to about 600 m near Meerssen. The boundary between fluvial and colluvial soils is very irregular, especially in front of tributary-valleys (cf. 3.6).

One of the most noticeable features of the soil map (Fig. 6) is that at practically every point of the valley the river has only formed one meander belt corresponding to coarse-silty soils (unit L). In general Figure 7 shows that coarse-silty soils (unit L) occur at the same places in the subsoil as in the upper part of the soils. The levees on both sides of the Geul are narrow. The total width of soils of unit L varies from a minimum of 50 m to about 350 m where some branches of the Geul run side-by-side near the castles of Genhoes and Schaloen and the Meerssen watermill.

Another noticeable feature is the comparative rarity of clayey basin soils and peaty soils, the main reason being the narrowness of the valley. Clayey and peaty

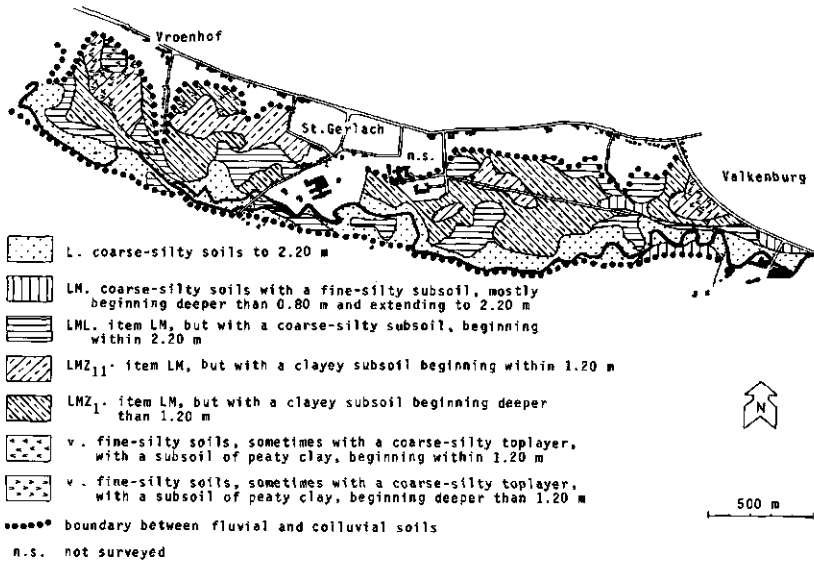


FIG. 7. Simplified soil map to 2.20 m of the Geul valley between Valkenburg and Vroenhof.

soils occurring at the surface (units with textural classes (M), Z and V) are always situated on the other side of the valley as where the river flows.

A typical feature of most map units is that the clay content increases with depth (Table II). It is only the coarse-silty soils of the levees that do not show this increase (Table II). The increase in clay with depth corresponds to the geogenesis of the Geul deposits. The subsoil is formed by material of the first stages, the upper part of the soil by material of later deposits with a coarser texture (see 3.2).

It was shown by cross-sections made in various parts of the valley that the surface level of a peaty soil in the basin position is often higher than that of a levee. At such sites river sedimentation was clearly impossible. In the basins or back swamps fluvial sedimentation might only have been possible after the peat had eroded, or else as a result of improved natural water discharge of the river or artificial drainage of the valley. It was only at certain points on the borders of the valley near slopes where springs occurred that good drainage was impossible and peat was unable to settle.

With the exception of the map unit L of the levees, all others are more or less complex, depending on textural changes in the soil profiles and the map scale. In some areas map units as (M)Z and (M)ZV are related, as they indicate the basin position of the valley. Map units as LM, LML, etc., denote the transition from levee to basin. These soils show the geogenesis of the two main stages of the fluvial soils. The most recent and upper part of the levees (L) has been deposited on a former basin situation (M), or with the same genesis the basin was early situated in a levee situation (L), as found in the oldest levee subsoil.

The soil map of Figure 6 shows a difference in soil conditions upstream and

TABLE II. Soil textures of two profiles. Profile Schin op Geul II, a basin soil (unit MV).

horizon	depth (cm)	particle size distribution				pH		organic matter %C	% CaCO ₃ (Wes- mael)
		< 2 μm	2-15 μm	16-50 μm	> 50 μm	KCl	H ₂ O		
A1	0-8	22.7	22.3	48.4	6.6	6.90	7.1	4.56	2.5
A1	8-16	22.9	21.9	48.6	6.6	6.97	7.1	3.36	3.1
A3	16-26	20.8	20.4	53.1	5.7	6.95	7.2	1.55	4.2
A3	26-37	20.4	23.1	54.2	2.3	7.11	7.3	0.81	0.7
B2	37-50	20.5	21.3	55.5	2.7	7.03	7.2	0.95	1.4
B2	50-62	29.4	29.6	39.9	1.1	6.77	7.2	2.05	0.4
IIC1	62-80	44.6	29.9	24.3	1.2	6.35	7.0	4.31	0.3
IIC2	+ 80	30.2	28.9	34.6	6.3	5.87	6.0	22.7	1.8

Profile Schin op Geul III, a levee soil (unit L).

horizon	depth (cm)	particle size distribution				pH		organic matter %C	% CaCO ₃ (Wes- mael)
		< 2 μm	2-16 μm	16-50 μm	> 50 μm	KCl	H ₂ O		
A1	0- 5	12.8	10.7	51.9	24.6	6.34	6.2	4.36	0.2
A1	5-10	12.4	10.2	52.1	25.3	6.53	6.3	3.46	0.1
A1	10-20	12.0	10.1	51.0	26.9	6.73	7.0	3.33	0.4
A3	20-35	13.0	10.7	58.1	18.2	6.10	6.6	1.32	0
B2	35-50	13.4	12.0	58.8	15.8	6.57	6.9	0.90	0
B2	50-65	13.6	12.0	59.4	15.0	7.05	7.4	0.47	0.3
B2	65-80	12.3	11.3	60.7	15.7	7.06	7.4	0.53	0.2
B3	80-95	11.4	9.9	61.4	17.3	6.67	7.1	0.43	0
B3	95-110	10.2	8.4	63.0	18.4	7.37	7.6	0.29	1.0

downstream from Valkenburg. Basins with fine-silty and clayey soils (M, Z) or peat (V), with or without some coarse-silty material in the upper part of the soil, are only well developed upstream from Valkenburg. Downstream they do not occur or are small. Coarse-silty soils predominate, e.g. more L and LM₂ of LM₃ than upstream where more LM₁ and LM₂ occur. The reason for this phenomenon is not clear. It could be a geological one as a difference in the valley fill on both sides of Valkenburg, or the effect of the Meuse on the sedimentation pattern of the Geul may not have extended beyond Valkenburg. It is not known how changes in the course of the Meuse and Geul may have affected the latter's sedimentation pattern. BECKERS (1929) reported a number of considerable changes. It would seem unlikely that this difference in soil conditions was connected with a different deforestation or occupation pattern upstream and downstream from Valkenburg.

Although the Geul has only formed a single meander belt, downstream from Valkenburg it was possible to survey an old river system. Particularly on the left of the valley between Geulhem and Rothem an old system is present in the

subsoil (Fig. 7). This system is also clearly indicated by soil carbonates (MIEDEMA, 1980).

Near Meerssen the Geul has three branches which must be connected with watermills. The soil conditions and soil carbonates of the branches, the Grote (Great) Geul and the Kleine (Small) Geul show that fluvial sedimentation must be fairly recent. The southern branch, the Geulke (little Geul) is a millrace which has scarcely led to any fluvial sedimentation (cf. the soil map).

3.6. FANS

The border between the fluvial soils of the Geul and the colluvial soils along the valley slopes bends towards the valley axis at points where tributary-valleys join the main valley (Fig. 6). In front of these tributary-valleys fan shaped bodies protrude into the main valley. The deposits of which the fans are made, usually are different from those of the adjacent Geul sediments. Clearly the sediments of these fans have been supplied through tributary-valleys. Although the deposits have a loess-like texture, they are different from the fluvial deposits of the Geul. This is most striking where clayey soils of the main valley are in contact with the outer fringes of the fans. In such cases the fan deposits have a coarser texture due to the sudden change in the slope of the tributary-valley, where it enters the plain of the main valley.

The different origin of the parent material is also revealed when masses of calcareous material have been eroded in the catchment area of the tributary-valley; there the fan deposits have calcareous soils. Carbonate detritus derived from the tributary-valleys has also affected the fluvial soils of the Geul (MIEDEMA, 1980).

It is clear from the shape of some fans that man was responsible. They do not have usual round shape, but a straight projection on the rounding (Fig. 8). The morphology of some of the fans gives evidence of human activity. Instead of the

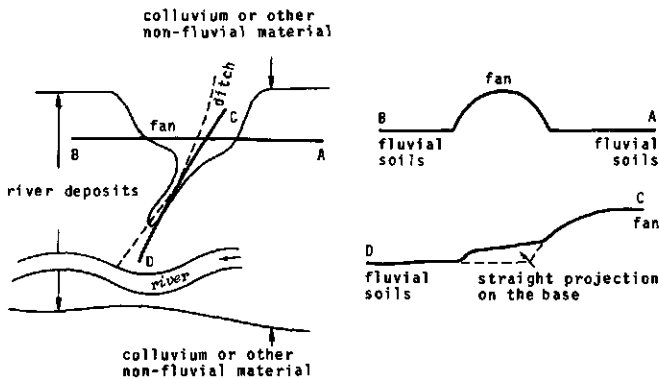


FIG. 8. Sketches of a fan in the Geul valley.

usual semi-circular form, a straight extension is present, that probably is a last remnant of a water course over the fan. The function of such a ditch was and still is to drain the farm land. During most of the year, however, the ditch is dry. The sediment, aggraded in the ditch is removed by the farmers and thrown over the sides. This spoil forms a kind of man-made artificial levee, preventing the surplus water running out of the ditch too fast. So as a result of the ditch, the last remnant of a small tributary in the tributary-valley, and by farmers' activities in cleaning the ditch, some fans have a straight projection instead of a round shape. Examples are found near Stokhem, Etenaken, in front of the Gerendal and near Vroenhof.

The fans are of recent date and of the same origin as the Geul deposits, viz. clearance of the forests for farming. The centre of the fan may be old where it connects with the point at which a tributary enters the Geul, but the extension of the fan is recent. At some sites the border of the fan overlies peat which means that the genesis of the fans, like that of the Geul deposits, is related to the erosion occurring after the deforestation of the loess area (HAVINGA and VAN DEN BERG VAN SAPAROE, 1980).



FIG. 9. Fan in front of a dry valley.

4. THE PRESENT LANDSCAPE

Only small and altered remnants have been left of the original marsh forest in the Geul valley. At present the valley consists of farmland, mainly pasture. In

earlier centuries, when the drainage was less efficient, a wide area of land was used as meadows. Names with the suffix 'beemd' ('meadow') are a relic of this agricultural land use. Marshy land adjoined the meadows, as indicated by place-names with the suffix 'broek' ('brook').

The difference between the levees and the basins is hardly visible in the landscape. In some places differences in kinds of grasses and herbs show the differences in water-table classes (Gt) of the levees and the basins. This gives a good indication of the hydrological condition, at least where pastures are not too intensively exploited.



FIG. 10. The attractive landscape of the Geul valley: pastures, trees, pollards, the river Geul (l.) and a millrace (r.).

The Geul valley landscape is very attractive (Fig. 10). It is a pastoral landscape and the many poplars and willows along the Geul and in lanes, pollards (willow, alders, ash, hornbeam, etc.), overgrown alder and hawthorn hedges along the meadows and paths give it a special character. Several species of birds find a good biotope in this landscape.

The recent erosion at the outer bends and sedimentation in the inner bends can be seen along the borders of the Geul. The most recent deposits are lower than the older river banks. The vegetation clearly responds to this habitat which is rich in carbonates and nitrogen. And it is only fair to add that river pollution and pollution of the environment and the river banks by human refuse create a great problem for landscape management.

Villages and other buildings are found on the hills along the valley. There are few buildings in the actual valley, e.g. a few farms, castles, water-mills and tea-houses. Unfortunately recent housebuilding (Schin op Geul) and a new motorway (near Meerssen) have upset the character of the valley.

As the valley is important for farming and recreation in South Limburg, we must be on guard against any undesirable development that could destroy the valley landscape. It should also be remembered that the pleasant valley landscape can only be saved for the future provided agriculture continues to remain its essential feature.

5. SUMMARY

By Dutch standards the Geul, a major tributary of the Meuse, is a fast-flowing river. Under present conditions the sedimentation by the Geul is different from the sedimentation under conditions when the loess landscape was under permanent vegetation.

Five stages in the geogenesis of the valley fill could be distinguished. The first stage is of pre-Holocene age, the other four are Holocene. The Pleistocene braided rivers had laid down gravel layers overlying Cretaceous material. In the beginning of the Holocene the Geul had a low activity. In the densely forested loess landscape the river mainly carried groundwater base flow; the suspended load was small. Only some clay was deposited, or else peat was formed.

This situation changed when the vegetation was cleared by man for agriculture. Bare soil became subject to erosion. Instead of penetrating the soil, more surplus water flowed laterally down the slopes. It caused higher and more irregular water levels and discharges of the Geul. The current velocity and sediment load of the river substantially increased. Owing to the coarse-silty and weak acidic top layers the loess soils were very liable to erosion. The river deposits now consisted of silty loess-like material.

Most soils have a textural trend that increase with depth. This increase in clay content corresponds to two main stages in deforestation and resulting erosion. In this part of South Limburg no settlements of Bandkeramik age have been found. Severe erosion occurred in or after the Roman era and the Middle Ages, when large parts of the South Limburg loess landscape were deforested and used for arable farming.

In recent times the Geul sometimes receives more water than before, as result of improved farming practices, paved roads and effluent water from households through sewerage. Under present conditions the Geul has an increased current velocity; the river cuts into its former deposits. The recent deposits are at a lower level. Sand predominates.

Most soils in the Geul valley have a coarse-silty top layer and a fine-silty subsoil. The legend of the soil map is based on three textural classes: L, M and Z

(respectively ca 10–20%, ca 20–30% and more than 30% lutum or clay), and V (peaty material and peat, i.e. more than ca 15% organic matter).

There is a relation between soil types and soil carbonates. Groundwater fluctuations have been distinguished in Gt classes. Levee soils have high Gt (VII), basin soils lower Gt's (V and lower).

The soil maps show a single meander belt with coarse-silty levee soils (L), clayey and peaty basin soils (M, Z and V) and soils in transition (LM, LML). The surface level of peaty soils sometimes is higher than that of a levee. At sites where springs occurred good drainage was impossible and peat was unable to settle.

The soil map shows a difference in soil conditions upstream and downstream from Valkenburg. Upstream from Valkenburg basin soils are well developed, downstream from Valkenburg a coarse-silty layer is overlying deposits with other textural classes. The reason for this phenomenon is not clear.

A noticeable feature of the valley are the fans in front of tributary-valleys. The border between the fluvial and the colluvial soils bends towards the valley axis. From the shape of some fans it is clear that man was responsible. Instead of the usual semi-circular form of a fan, a straight projection is present, that probably is the last remnant of a water course over the fan. The function of such a ditch was and still is to drain the farm land. The farmers removed the aggraded sediment in the ditch and threw over the sides.

The present landscape is a landscape of pastures, trees and pollards, hedges, etc. In some places several kinds of grasses and herbs still indicate the hydrological conditions. Birds find a good biotope in this landscape.

The valley is important not only for farming, but also for recreation. Unfortunately recent developments as housebuilding, a new motorway and pollution, have upset the character of the valley. The pleasant character of the valley has mainly been created by agricultural use and it can only be saved for the future provided agriculture continues to remain its essential feature.

6. SAMENVATTING

GEOLOGIE EN BODEMGESTELDHEID VAN HET GEULDAL

De Geul ontspringt bij Eynatten in België. De Geul heeft een lengte van ongeveer 56 km, waarvan 2/3 deel in Nederland (fig. 1). De Geul is een snelstromende rivier, met een gemiddeld verhang van 3 m/km (minimum 1,33 m/km bij Houthem, maximum 7,62 m/km bij Epen). Het gemiddeld debiet van de Geul bij Meerssen bedraagt ongeveer 2300 l/sec (minimum 960 l/sec, maximum 65.000 l/sec).¹ Overstromingen van lage terreinen komen nog regelmatig voor. Grote overstromingen van het gehele dal zijn zeldzamer.

¹ Gegevens van de Provinciale Waterstaat van Limburg.

Uit de bodemkartering en geologische doorsneden is een goed beeld van de Holocene opvulling van het Geuldal verkregen. De geologische opbouw en de bodemgesteldheid weerspiegelen duidelijk de gevolgen van de ontginning en het agrarisch landgebruik (ontbossing, erosie) in dit deel van het Zuidlimburgse lössgebied.

In de geologische opbouw kunnen vijf fasen worden onderscheiden. In fase I (fig. 3a) valt de laat-Pleistocene dalopvulling met grof materiaal, afgezet door een verwilderde rivier.

Fase II (fig. 3b) valt in het oudere Holoceen, toen Zuid-Limburg nog geheel met bos was bedekt. In die tijd had de Geul een veel kleiner en regelmatiger debiet en voerde vooral bronwater af. Er werd weinig mineraal materiaal meegevoerd; de sedimentatie beperkte zich tot zware klei. Ook veen hoopte zich op.

In fase III (fig. 3c) trad er een verandering in de activiteit van de Geul op, die een gevolg was van een veranderend leefpatroon van de mens. De mens was van jagen en vissen en verzamelen van voedsel overgegaan op landbouw, wat gepaard ging met ontbossing. Hiervan was erosie het gevolg. De eerste landbouwers, de Bandkeramische bewoners van Zuid-Limburg, troffen op de lössgronden met hun oorspronkelijke lichte en zwakzure bovengronden een betrekkelijk licht bos aan. Zowel de aard van de begroeiing als de bodemkundige eigenschappen van de lössgronden betekenden een gunstige situatie voor de vestiging van de landbouw.

Doordat de agrarische activiteiten van de Bandkeramische bewoners zich vooral op de plateaus afspeelden, terwijl de hellingen met bos bedekt bleven, bleef de (geringe) erosie en daarmee ook de sedimentatie door de Geul beperkt. De grote Bandkeramische woonplaatsen waren ver buiten het Geuldal gelegen. In die tijd zal het oorspronkelijke, zeer rustige karakter van de Geul dan ook maar weinig kunnen zijn veranderd. Dit werd anders in de Romeinse tijd toen grote delen van het Zuidlimburgse lössgebied werden ontbost. Erosie trad in versterkte mate op, de rivieren – ook de Geul – kregen meer water en slib af te voeren en er vond veel sedimentatie plaats. Het transporterend vermogen van de Geul was zozeer toegenomen, dat er in plaats van zware klei en veen voortaan afzettingen van een lichtere textuur, voornamelijk lössachtig van samenstelling, sedimenteerden. Het is in het algemeen nog onzeker of de sterkste erosie in het begin of aan het eind van een belangrijke bewoningsperiode plaatsvindt.

Ook in de Middeleeuwen trad er een sterke erosie op. De Geul kreeg nu periodiek zelfs nog meer water af te voeren en had ook hogere stroomsnelheden dan voorheen. Dit leidde tot een versterkte opslibbing met lichtere sedimenten (fase IV, fig. 3d). Veel bodemprofielen bezitten een textuuropbouw van licht-op-zwaar, zodat er twee sedimentatiefasen moeten zijn geweest. Dit moet weer in verband staan met twee belangrijke bewoningsperioden waarin landbouwactiviteiten met het optreden van erosie plaatsvonden. In de tijd na de Middeleeuwen is de intensiteit van sedimentatie nog verder toegenomen tengevolge van de voortgaande ontbossing, de toegenomen ontwatering en de vergrote waterafvoer (fase V, fig. 3e). De Geul sneed zich nu langzamerhand in tot in de Pleistocene ondergrond. De jongste afzettingen zijn zandig en kalkhoudend en liggen lager

dan voorheen (fig. 4).

In het lössachtige sediment zijn drie textuurklassen onderscheiden met resp. 10–20%, 20–30% en meer dan 30% lutum, die op de kaart en hieronder zijn aangeduid met L, M en Z. Venig materiaal of veen is weergegeven als V. De oeverwallen hebben als textuurprofiel L tot 120 cm, vaak ook tot 220 cm. Bodemprofielen buiten de oeverwallen vertonen naar onderen meestal een toename in textuur. In de komgebieden komt in het textuurprofiel de tweeledige opbouw als gevolg van de verschillende erosie- en sedimentatie-intensiteit in de op elkaar volgende kultuurperiodes fraai tot uiting.

Voor zover de bodemprofielen kalk bevatten, zijn dit voornamelijk bodemprofielen in oeverwalpositie met een lichte textuur (L). Fig. 5 geeft voor een gedeelte van het Geuldal een vereenvoudigde grondwaterfluctuatiekaart ('Gt'-kaart) weer. Het beeld op deze kaart vertoont een nauwe samenhang met de aanwezigheid van oeverwallen en komen op de bodemkaart (fig. 6).

De bodemkaart is gebaseerd op de onderscheiding van de textuurklassen L, M en Z en op de aanwezigheid van veen (V), dit alles tot op een diepte van 120 cm (Voor fig. 7 tot op een diepte van 220 cm). Zowel de fluviatiele als de colluviale gronden hebben een lössachtige textuur. Als grens tussen beide is genomen de overgang van een vlak gelegen naar een hellende bodem. Deze grens verloopt onregelmatig, vooral bij die zijdalén waarvoor een colluviale lob ligt.

Sommige van deze lobben, zoals die bij Vroenhof, bezitten een merkwaardig smal uitsteeksel (fig. 8). Dit is ontstaan vooral als gevolg van agrarisch gebruik om het uiteinde open te houden van de zijbeek, die alleen periodiek, namelijk gedurende tijden van veel neerslag, snel invallende dooi en zware regenval bij onweersbuien, in korte tijd veel water afvoerde en die in en voor de uitmonding in het Geuldal veel slib sedimenteerde. Daarom werd dit deel van de zijbeek regelmatig uitgediept en verbreed. Het grondoppervlak ter weerszijden hiervan is daardoor voortdurend hoger geworden.¹

De Geul heeft slechts één stroomgordel gevormd. De breedte van de oeverwal (eenheid L) is gering, soms maar 50 m. De plaatsen waar zware klei en veen voorkomen, in de kommen, liggen altijd aan de tegenovergestelde zijde van het dal als die waar de stroomgordel ligt. Veel bodemprofielen hebben een kleigehalte dat toeneemt bij grotere diepte.

Er bestaat een verschil tussen de bodemgesteldheid stroomopwaarts en stroomafwaarts van Valkenburg. Kommen met zware klei en veen zijn stroomopwaarts van Valkenburg beter ontwikkeld; stroomafwaarts is er overal een dek van licht materiaal aanwezig. De oorzaak van dit verschil is vooralsnog onduidelijk.

Vermeldenswaard is nog dat tussen Geulhem en Rothem in de ondergrond een oud riviersysteem uit het Holoceen aanwezig is en dat stroomafwaarts van Meerssen de Geul drie takken heeft. Uit de bodemgesteldheid komt naar voren dat twee ervan, de Grote Geul en de Kleine Geul, betrekkelijk jong moeten zijn.

¹ Een dergelijke beek voert vaak de naam van vloedgraaf.

Het Geulke lijkt een echte molenbeek.

Van het oorspronkelijke broekbos in het Geuldal is niets over. Alleen in veld- en plaatsnamen komt de relatie met het oorspronkelijke 'broek' nog uit. Het dal is geheel een agrarisch gebied. Vroeger was het voornamelijk als hooiland ('beemd') in gebruik.

Op veel plaatsen is er nog een betrekkelijk kleinschalig zeer afwisselend landschap met wei- en hooilanden. De grassen- en kruidenvegetatie vertoont op verschillende plaatsen nog duidelijk verband met de hydrologische bodemgesteldheid. Populieren en wilgen langs de Geul en in lanen of als bossen, geknotte bomen van velerlei soort, heggen langs de paden en percelen verhogen de landschappelijke waarde en zijn tevens een goede biotoop voor vogels en insecten. Helaas plegen vervuilingen van velerlei soort, bebouwing (o.a. Schin op Geul), campings, wegen (autosnelweg) en bepaalde agrarische activiteiten een aanslag op het landschap.

Het Geuldal heeft zowel voor de landbouw als voor de recreatie een belangrijke functie. Verdere ongewenste ontwikkelingen moeten worden voorkomen, waarbij bedacht moet worden dat de landbouw een essentieel element in het landschap van het Geuldal is.

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