INCIDENCE AND DISTRIBUTION OF CARBONATES IN THE SOILS OF THE MEANDERING RIVER GEUL

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CONTENTS

1. INTRODUCTION

The published evidence gives little detailed information on the incidence and distribution of carbonates in fluvial soils of the large meandering rivers. Levee soils are predominantly calcareous and a description has been given of their progressively deeper decalcification with age of the levee, leading to complete decalcification of some of the oldest soils (PONS, 1957; VAN DEN BROEK and VAN DER MAREL, 1964; SOIL SURVEY INSTITUTE, 1977). Practically all basin soils are non-calcareous, chiefly as a result of decalcification during sedimentation (BENNEMA, 1953; PONS, 1957). This proces has been described in detail for Dutch estuarine and marine sediments (BENNEMA, 1953; ZONNEVELD, 1960; VAN DER SLUYS, 1970).

But the complex nature of the incidence and distribution of carbonates in the soils of the meander belts of the large Dutch rivers is imperfectly understood.

The fluvial soils of the Geul are a small-scale model of the sedimentation system of the meandering river (VAN DE WESTERINGH, 1980). During a soil survey of this area the presence of carbonates, as determined by the reaction of the soil with 2 M HCl, was one of the characteristics checked at every 10 cm of each augering. At a number of sites the presence of carbonates in the upper 1.2 or 2.2 m of the soils along the Geul was investigated in detail by augerings 1–20 m apart. Micromorphological and chemical observations were made of samples of two profiles, and water samples of the river, two tributaries fed by wells and a well discharging into the river were analysed.

From these data two models were derived with the objective of explaining the incidence and distribution of carbonates in the soils of the meander belt of the Geul. These models are discussed in this paper and it is hoped they may throw more light on the complex incidence and distribution of carbonates in the fluvial soils of the meander belts of the large rivers of the Netherlands.

Some help will also be provided in distinguishing sedimentation phases and former river systems according to the incidence of carbonates in the deeper subsoil.

The presence of fans along the valley border in front of dry valleys (VAN DE WESTERINGH, 1980) is a characteristic feature of this part of the Geul valley and the associated carbonate incidence will be discussed.

2. OBSERVATIONS, INTERPRETATION AND DISCUSSION

2.1. CARBONATES DEPOSITED AS PART OF THE SEDIMENT LOAD

VAN DEN BROEK and VAN DER MAREL (1964) have shown that the carbonates in the alluvial soils of the Geul are almost exclusively $CaCO_3$.

To check the possibility of chemical precipitation of $CaCO_3$ from the water of the Geul, analyses were made of water samples of the river, a well and two tributaries fed by wells. The results are presented in Fig. 1. The well and tributaries fed by wells (from Cretaceous limestone) have the highest concentrations of Ca, HCO_3 and H_4SiO_4 (owing to the solution of Cretaceous limestone and silica leaching from overlying Pleistocene terrace deposits) and have distinctly lower Mg, K, Na, Cl and SO_4 contents than the river samples. Pollution by inorganic fertilizers, organic manure and other human influences may be responsible for the higher concentrations of these ions in the river samples. Intermediate contents are found downstream of the confluence of the Geul with water from wells and tributaries. The pH is fairly constant and ranges from 7.1 to 7.3.

Calculations were made of the ionic strength and the ion activity product (I.A.P. at 25°C, 20°C, 15°C, 10°C and 5°C). The former is highest in the wells

TABLE 1. Results of water analyses of the Geul (mol m^{-3})

Sample	($\frac{1}{2}Ca^{2+}$)	($\frac{1}{2}Mg^{2+}$)	(Na^+)	(K^+)	(HCO_3^-)	(Cl^-)	($\frac{1}{2}SO_4^{2-}$)	(H_4SiO_4)	pH	I (a)	I.A.P.: K_{so} (f) 5°C	10°C	15°C	20°C	25°C
Geul near Wylre	4.55	0.67	0.91	0.15	4.06	0.80	1.24	0.47	7.2	.0094	0.30	0.41	0.55	0.70	0.96
Geul near Etenaken	4.51	0.69	0.78	0.13	3.96	0.88	1.13	0.40	7.3	.0092	0.37	0.50	0.67	0.86	1.19
Geul near Keutenberg	4.51	0.69	0.72	0.12	4.03	0.80	0.97	0.40	7.3	.0090	0.38	0.51	0.68	0.88	1.21
Geul near Schin op Geul	4.65	0.66	0.70	0.11	4.18	0.70	1.17	0.44	7.3	.0093	0.41	0.54	0.73	0.94	1.29
Geul near Valkenburg	4.59	0.64	0.77	0.11	4.15	0.90	1.13	0.53	7.3	.0093	0.40	0.53	0.72	0.92	1.27
Well/tributary Etenaken	5.54	0.57	0.35	0.07	5.03	0.64	0.72	0.88	7.3	.0099	0.55	0.76	1.03	1.32	1.83
Well Keutenberg	5.90	0.43	0.19	0.03	4.85	0.66	0.76	0.94	7.1	.0100	0.37	0.49	0.67	0.85	1.18
Well/tributary Schin op Geul	5.31	0.54	0.27	0.06	4.85	0.60	0.65	0.84	7.3	.0099	0.52	0.69	0.92	1.20	1.65
Etenaken downstream	4.95	0.65	0.62	0.11	4.42	0.72	0.98	0.65	7.2	.0095	0.36	0.48	0.65	0.84	1.15
Keutenberg downstream	5.50	0.47	0.29	0.05	4.76	0.60	0.76	0.74	7.2	.0096	0.43	0.57	0.77	0.99	1.36
Schin op Geul downstream	4.67	0.65	0.69	0.11	4.21	0.70	1.13	0.37	7.3	.0093	0.41	0.54	0.73	0.95	1.30

a) I = Ionic strength $= \frac{1}{2}\sum m_i \times z_i^2$ (m_i = concentration ion i in mol dm^{-3}; z_i = valence of ion).

b) Davies equation: $\log \gamma_i = A \times z_i^2 \left(\frac{\sqrt{I}}{1+\sqrt{I}} - 0.2\,I\right) \rightarrow \gamma Ca^{2+}$ and $\gamma HCO_3^- \rightarrow [Ca^{2+}]$ and $[HCO_3^-]$

c) $\frac{[H^+][CO_3^{2-}]}{[HCO_3^-]} = K \rightarrow [CO_3^{2-}]$

d) I.A.P. = Ionic Activity Product $= [Ca^{2+}][CO_3^{2-}]$

e) $\frac{[Ca2^+][CO_3^{2-}]}{[CaCO_3]} = K_{so}$

f) $\frac{I.A.P.}{K_{so}}$ = degree of saturation

The values used for the constants A, K and K_{so} at various watertemperature are taken from GARRELS & CHRIST (1965) and tributaries. Dividing the I.A.P. by the solubility product (K_{so}) of $CaCO_3$ gives the degree of $CaCO_3$ saturation at a given temperature of the water. No supersaturation with $CaCO_3$ occurs at normal water temperatures of the Geul ranging from 3°C to 15°C (MRS. BAKKER, pers. comm., 1979). Chemical precipitation of $CaCO_3$ can therefore be ruled out, nor was it observed.

The carbonate particles in the Geul sediments must be derived from sedimentation as part of the sediment load of the river. This conclusion is borne out by a micromorphological study of two levee soils (Schin op Geul and Kapolder). The size of the observed carbonate skeleton grains found scattered in the groundmass is comparable to that of the other skeleton grains; it is larger in the sandier Kapolder than in the siltier Schin op Geul profile. The morphology of the carbonate particles observed ranges from coarse to fine crystalline. The carbonate particles are derived from Cretaceous limestone and calcareous loess. Erosion may bring this material down to the Geul valley where it is taken up by the Geul and deposited downstream. Carbonate particles are also produced by erosion of the river's fluvial calcareous deposits and resedimentation downstream. The coarse crystalline type of carbonate particles originates from limestone fragments and calcareous loess. The fine crystalline carbonate particles are probably secondary carbonates derived from eroded loess profiles redeposited by the Geul and now found scattered in the groundmass. The most recent sediment of the Geul in still unhomogenized sandy loam terraces on a lower elevation than the levee deposits (VAN DE WESTERINGH, 1980) has an invariably high $CaCO_3$ content (8%–10% w/w). Determinations of material showing effervescence with 2 M HCl show that the $CaCO_3$ content in the older, completely homogenized brown silt loam levee soils along the river course ranges from 2–3% (w/w), which is in agreement with the contents given by TEUNISSEN VAN MANEN (1958) and VAN DEN BROEK and VAN DER MAREL (1964). The latter refer to a similar difference in $CaCO_3$ content between fresh sediment and levee soils of the Meuse.

2.2. INCIDENCE AND DISTRIBUTION OF CARBONATES ASSOCIATED WITH THE FLUVIAL SEDIMENTATION REGIME

The sedimentation pattern along the meandering Geul is due to accretion of the inner and erosion of the outer bends. During short periods of flooding sediment is deposited over the entire floodplain. The carbonate distribution pattern was studied in detail in several meander belt sections by augerings 1–20 m apart. The presence of carbonates in the groundmass in layers of a minimum thickness of 20 cm, irrespective of the relative amounts of $CaCO_3$, was mapped in 7 legend units. These are based on a division of the upper 1.2 m into three parts by arbitrary boundaries at 40 and 80 cm. The legend units are shown in Fig. 2.

2.2.1. The simple model

Fig. 2 shows some representative inner bends in which we observe a succession

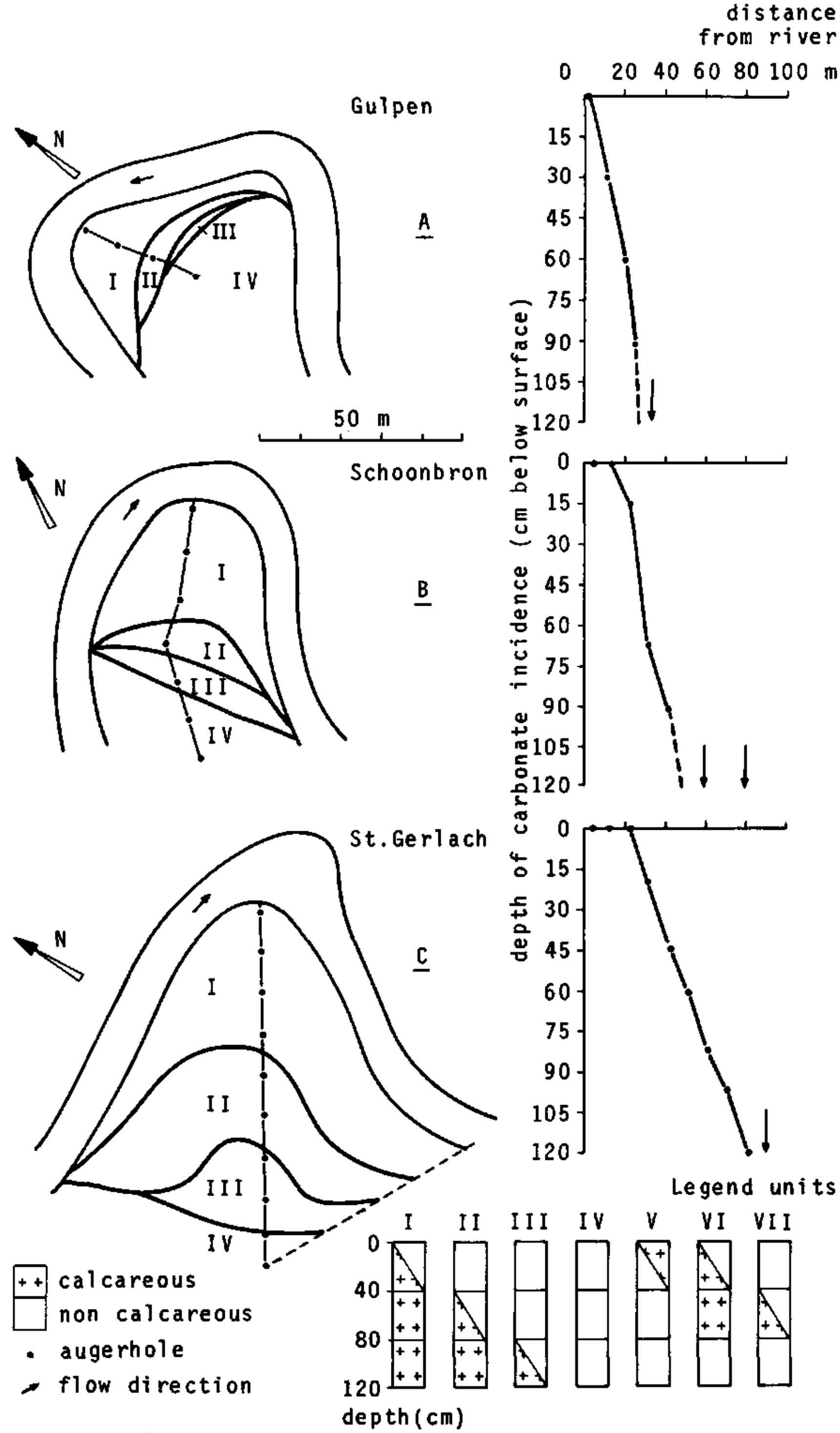


FIG. 2. Carbonate distribution pattern following the simple model in some representative inner bends, and depth of carbonate incidence as a function of the distance from the river.

of arcuate bodies representing legend units I, II and III at an increasing distance from the river. The location of these bends is indicated in Fig. 6. At a still greater distance from the river no carbonates are found within a depth of 1.2 m (legend unit IV).

The accretion of the sediment in such inner bends shows corresponding time-dependent arcuate bodies, thus indicating a difference in age in the sediments in the direction mentioned. The outer bends are in an erosive position, so that the sediment is older than that found in inner bends. It is therefore conceivable that the outer bends contain no carbonates or units with carbonates starting at a greater depth. The micromorphology of the Kapolder (unit I) and Schin op Geul (unit III) profiles shows that the primary carbonate skeleton grains are severely corroded near the boundary between calcareous and non-calcareous material. Secondary carbonates were occasionally observed in and around voids (calcitans and neocalcitans) (Fig. 3), this being due to decalcification. The fact that secondary carbonates were only occasionally observed in the field or in thin sections is due to the discharge of the dissolved $Ca(HCO_3)_2$ by the groundwater which fluctuates with the level of the river. The shape of the graphs showing the depth of carbonate incidence as a function of the distance from the river (Fig. 2) is determined by the fact that the rate of accretion of an inner bend increases with increasing excentricity of the meander combined with decalcification. The latest deposits show shallower decalcification and were deposited over a shorter period of time.

Hence the carbonate distribution pattern is caused by decalcification as a function of the age of the sediment, as determined by the sedimentation pattern in the accreting inner bend. The oldest deposits are farthest from the river in an inner and in outer bend position and have been decalcified to the greatest depth. In the older, deeply decalcified profiles, weak illuvation features were observed in the form of channel matri-ferri-argillans as described by VAN SCHUYLENBORGH *et al.* (1970) in a non-calcareous Geul profile.

2.2.2. *The interference model*

The pattern found in inner bends may be more complex. Fig. 4 shows the observations in two such bends. Their location is also shown in Fig. 6. The pattern observed cannot be explained with the use of the simple model discussed above. In Fig. 4A legend unit I occurs along the river in the form of a wider strip in the eastern part of the bend with an east-west oriented extension, and a fairly narrow strip in the western part. A zone with legend unit II accompanies the zone with unit I, and an island with legend unit III occurs in the western part of the bend. To the north no carbonates were found within a depth of 1.2 m (legend unit IV), but this lies outside the accretion area of the bend.

This asymmetrical pattern of carbonate incidence does not correspond to the accretion asymmetry of the present shape of the meander bend, as one would expect a wider strip of recent sediments in the western part (cf. also the patterns in Fig. 2). The east-west extension of unit I is topographically somewhat lower and scattered coarse, gravelly bedding material was found within a depth of 1.2 m.

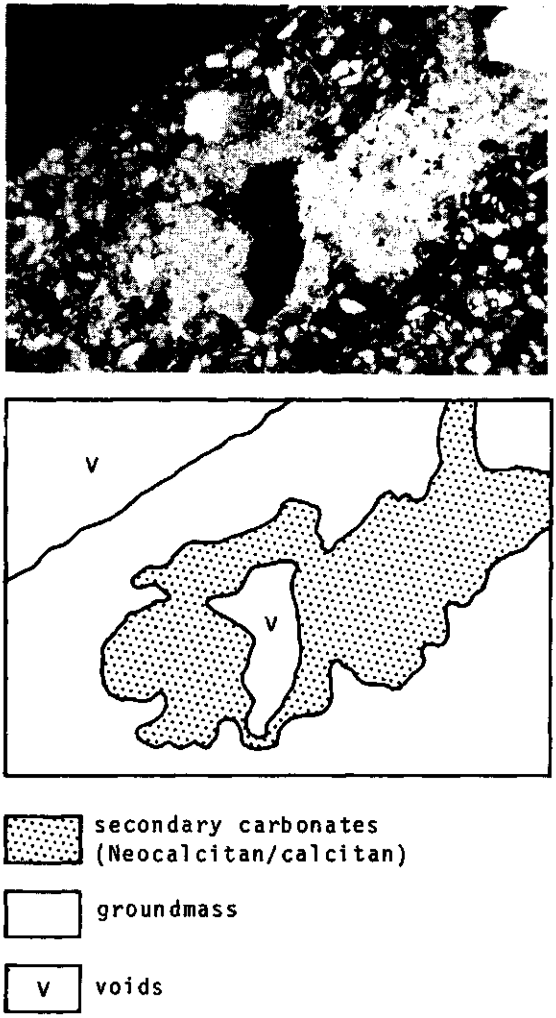


FIG. 3. Secondary carbonates in and around voids in the subsoil of the Schoonbron inner bend.

It would seem likely that changes in the river bed inside the meander belt interfered with the pattern of the simple model. The former channels were filled with more recent calcareous material to almost the same level as the surrounding soils, so that their profiles are not decalcified to the same depth. This can also be seen in the graph showing the depth of carbonate incidence as a function of the distance from the river (Fig. 4B). The Tranchot topographical map of 1803–1820 shows a meander of the same shape; hence the assumed former meander must antedate 1800.

The example in Fig. 4C comes from a part of the Geul valley where TEUNISSEN

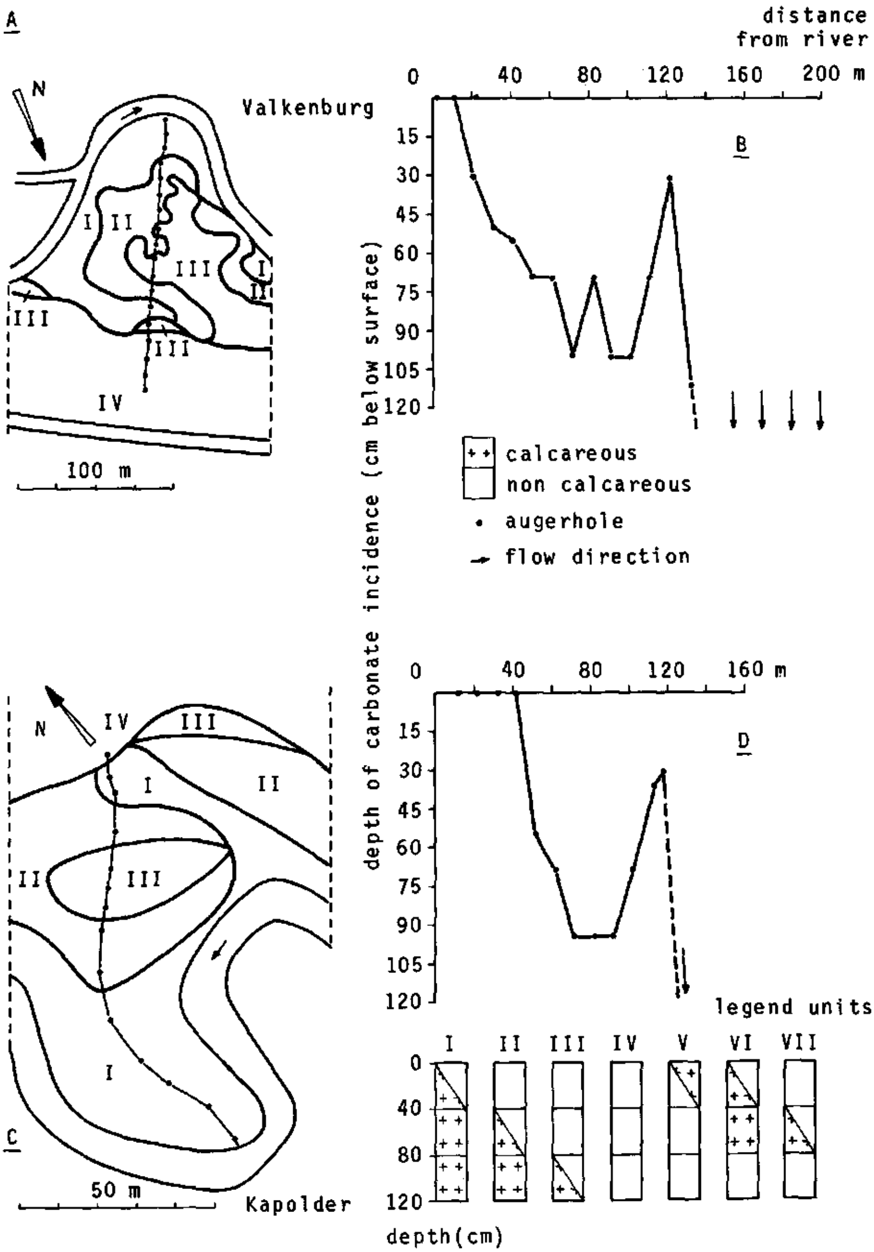


FIG. 4. Carbonate distribution pattern following the interference model in some representative inner bends, and depth of carbonate incidence as a function of the distance from the river.

VAN MANEN (1958) carried out a very detailed soil survey. He found distinct former channels which are responsible for the pattern of carbonate incidence and the associated graph of depth of carbonate incidence as a function of the distance from the river (Fig. 4D). Here too we find an island of decalcified soils surrounded by an area of shallower decalcification.

It can also be seen from Fig. 6 that changes in the river bed must be taken into account to explain the distribution pattern of carbonates; here the old channels near Oud Valkenburg and cut-off meanders near Etenaken are still clearly visible in the field and the distribution pattern of carbonates is in agreement with the sedimentation pattern of the former course of the Geul according to the simple model.

2.2.3. *Sedimentation due to flooding*

Sedimentation due to flooding is responsible for the more heavily textured soils in the transition and basin position (texture classes M and Z; VAN DE WESTERINGH, 1980). These soils are usually non-calcareous as a result of complete syn-sedimentary decalcification under conditions of poor drainage (BENNEMA, 1953; PONS, 1957; ZONNEVELD, 1960; VAN DER SLUYS, 1970). Minor amounts of pyrites and spherical iron hydroxides as oxidation products were observed in the peaty subsoil in thin sections of a basin profile near Schin op Geul and these may have speeded up the process of syn-sedimentary decalcification. The thin layer of L material covering more heavily textured deposits upstream of Valkenburg belongs to a more recent sedimentation stage (VAN DE WESTERINGH, 1980). This layer having been deposited in areas of poor drainage remote from the river, it may have been completely decalcified by a syn-sedimentary process. Alternatively, its age may be such that it has lost its carbonates by the decalcification process described for the levee deposits. But downstream of Valkenburg this deposit is more wide-spread and thicker and is still not completely decalcified. For this reason the extent of carbonates associated with the sedimentation regime of the Geul increases downstream of Valkenburg and calcareous soils are no longer exclusively found in inner bends.

2.2.4. *Subsoil carbonates*

The incidence and distribution of subsoil carbonates (between 1.2 and 2.2 m), on which data are available from 1976, 1977 and 1978 and from deep augering sequences, may provide evidence to support VAN DE WESTERINGH's (1980) theories of important changes in the course of the Geul during its sedimentation history (Fig. 5). In this area the subsoil carbonates are found in lightly textured deposits underlying more heavily textured transition and basin deposits. In the present basin area former filled-in channels can be identified in the field by their somewhat lower topography, pointing to changes in the river bed. This has also been found in other areas now in a basin position with respect to the Geul.

But in extensive areas along the Geul the carbonate incidence in the subsoil is merely the continuation of this incidence in the upper 1.2 m. In such cases the decalcification sequence is extended by types with carbonates starting pro-

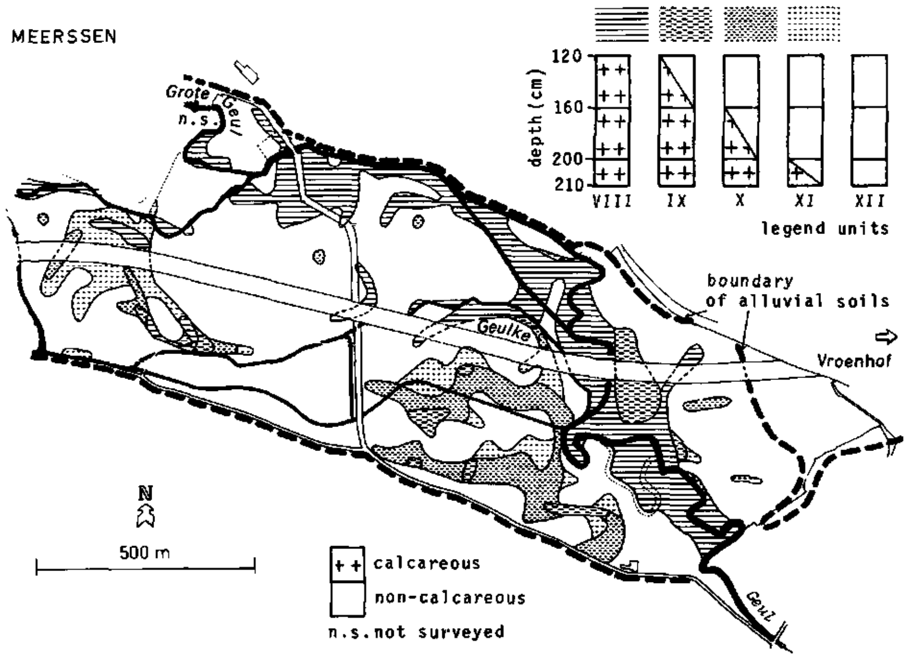


Fig. 5. Incidence and distribution pattern of subsoil carbonates (between 1.2 and 2.2 meters) in a selected area of the Geul valley.

gressively deeper in the subsoil between 1.2 and 2.2 m only, indicating a still deeper decalcification in older deposits at a larger distance from the Geul (sequence I–II–III–IX–X–XI–IV + XII). The texture of these soils remains L throughout the profile.

2.2.5. *Distribution of carbonate incidence associated with the sedimentation of the Geul*

Inspection of the carbonate distribution map (Fig. 6), bearing in mind the theories outlined above, shows that in the south-eastern part of the survey area between Partij and Gulpen only very limited amounts of carbonates along the Geul are found in clearly distinguishable former channels. This agrees with the observations made by VAN DEN BROEK and VAN DER MAREL (1964). The small amount of carbonates is due to the almost complete absence of steep Cretaceous limestone slopes south of Partij. The loess plateaus are not highly dissected and are mainly grassland and forest. Wells feeding the tributaries are derived from the Vaals formation (glauconitic green sand and clay of Cretaceous age; MEERMAN, 1975).

Between Gulpen and Wijlre the carbonates increase along the Geul. Near Wijlre in particular this part of the valley has suffered from fairly frequent flooding (MEERMAN, 1975), so that most of the levee soils may be relatively recent and not completely decalcified. Both the simple model (Fig. 2A) and the interference model are needed to explain the carbonate distribution. TEUNISSEN VAN MANEN (1958) surveyed part of this area and identified distinct former channels within the levee deposits where the interference model has to be used (Fig. 4C, D). Steep Cretaceous limestones slopes occur with very active wells discharging into the Geul and its Eyserbeek tributary (MEERMAN, 1975). The plateaus are more heavily dissected and mainly arable.

Between Wijlre and Valkenburg the carbonates are chiefly found in inner bends, following the simple model (Fig. 2B). Near Oud Valkenburg the carbonate incidence in former channels is very clear. One of the many active wells from Cretaceous limestone in this section discharging into the Geul was sampled and analysed (Fig. 1). The loess plateaus are fairly heavily dissected and are mainly arable.

Downstream of Valkenburg to the division of the Geul in two branches (near Vroenhof) carbonates are also more frequent around outer bends, although in a narrower strip and more deeply decalcified than in inner bends. The distribution can usually be explained by the simple model (Fig. 2C), although the interference model is occasionally needed (Fig. 4A, B). Steep Cretaceous limestones slopes border the valley to the south, but tributaries of the Geul from the north are fed by wells from the Oligocene Cerithien clay overlying Cretaceous limestone (MEERMAN, 1975). The plateaus are less highly dissected and mainly arable.

From the river fork near Vroenhof to the confluence of the three branches west of Meerssen carbonates are found in extensive areas between Grote Geul and Geulke with relatively shallow decalcification. Islands of unit IV surrounded by calcareous soils are a striking feature (Fig. 7A). They are usually surrounded by soils decalcified to 40–80 cm, and surrounded in turn by soils decalcified to 0–40 cm. Many former filled-in channels were observed in the field in the neighbourhood of the unit IV islands. The latest sedimentation phase of L material is widespread in this part of the valley; it is still calcareous and overlies more heavily textured deposits within a depth of 1.2 m (VAN DE WESTERINGH, 1980). This explains why units VI and VII are frequently found as shallower representatives of I and II. The extent and thickness of this latest deposit may be read from Fig. 7B (depth of carbonate incidence in this area). A clear picture of the sedimentation history of this area is obtained by combining Figs. 7A and B with Fig. 5 and comparing the result with the soil map of this part of the valley (VAN DE WESTERINGH, 1980). The carbonate distribution pattern results from the application of the interference model to larger areas; this will no doubt have to be done even more frequently when carbonates are distributed in the soils of the large rivers. Along the branches of the Geul the simple model can be successfully used.

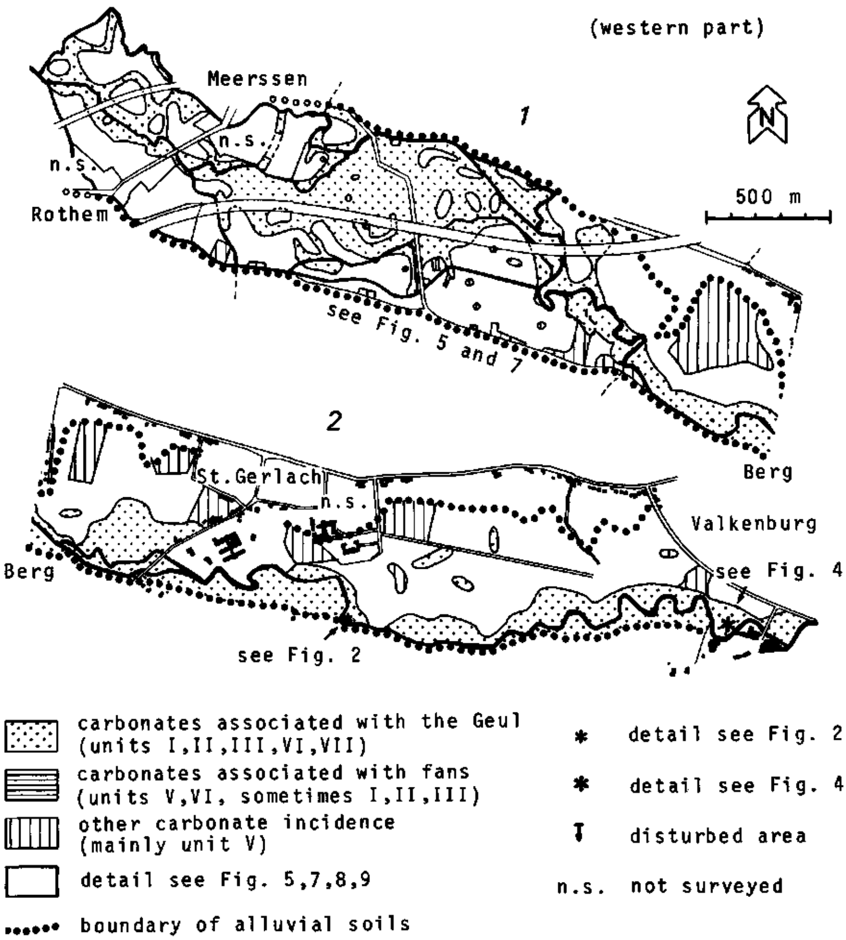
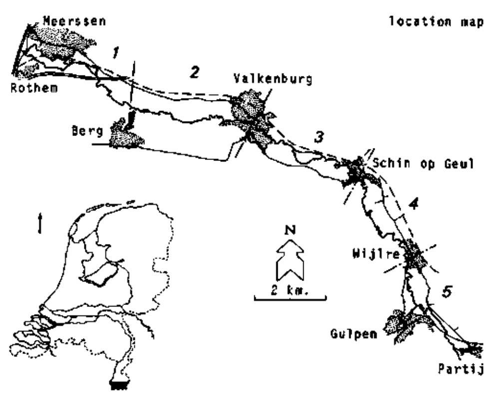
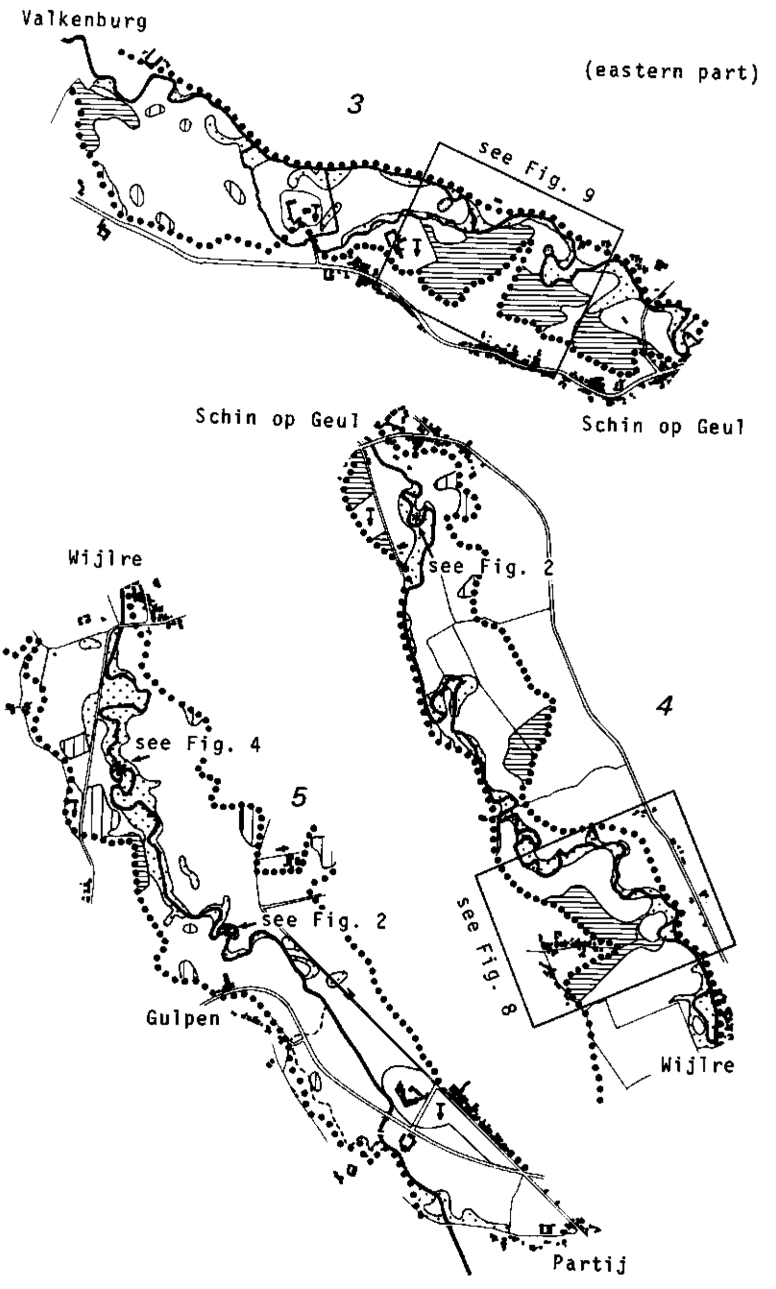
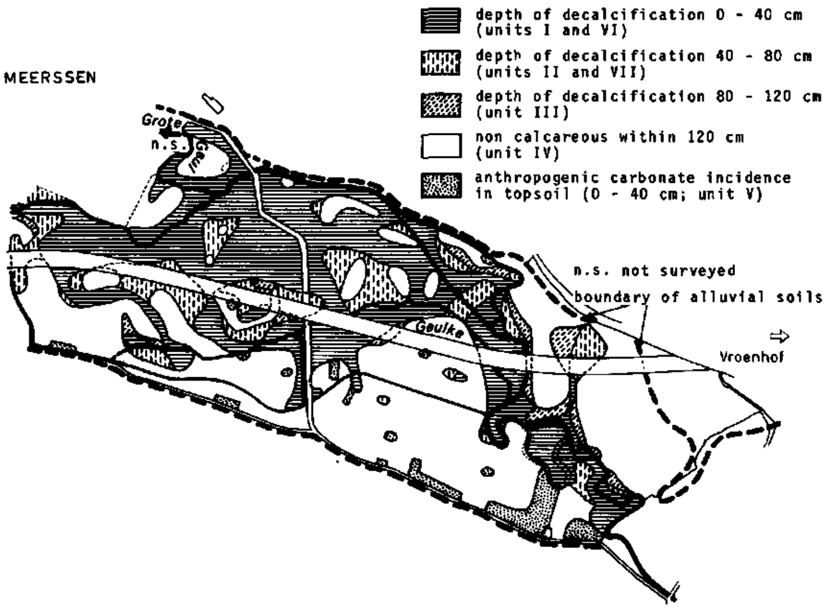


FIG. 6. Distribution of carbonate incidence in the soils of the river Geul (western part and eastern part).




Valkenburg
(eastern part)
3
see Fig. 9
Schin op Geul
Schin op Geul
Wijlre
see Fig. 2
4
see Fig. 4
5
see Fig. 2
see Fig. 8
Gulpen
Wijlre
Partij



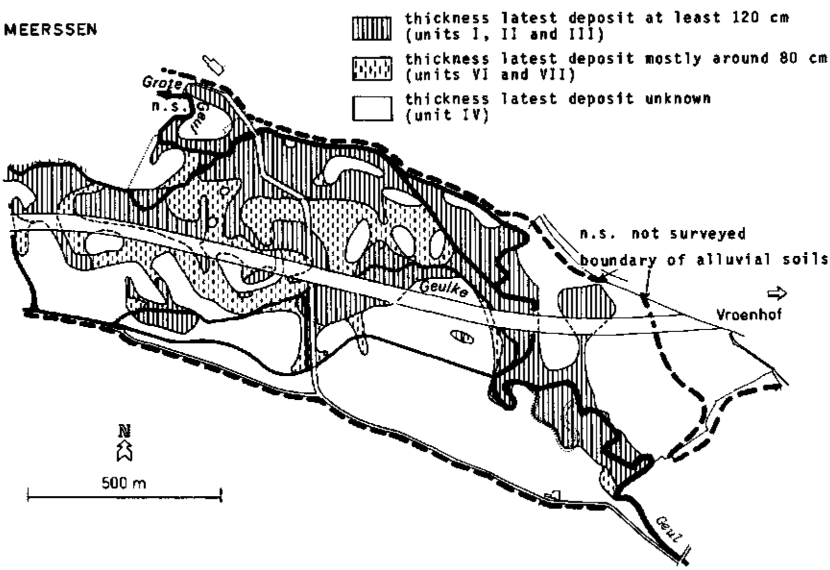


FIG. 7A. Carbonate incidence and depth of decalcification in an area with extensive deposits of the latest sedimentation phase.

FIG. 7B. Thickness of the deposits of the latest sedimentation phase based upon the depth of carbonate incidence, ignoring the depth of decalcification and anthropogenic influences.

2.3. CARBONATES ASSOCIATED WITH FANS

Fans are a characteristic feature of the Geul valley and occur along the valley border in front of dry valleys cutting into Cretaceous limestone or Tertiary deposits. The formation of these fans is described by VAN DE WESTERINGH (1980).

Where these fans originate from valleys cutting into Cretaceous limestone, the deposited material is calcareous and large areas of carbonates are found near Gulpen, near Stokkem, between Etenaken and Schin op Geul, between Schin op Geul and Oud Valkenburg. Fig. 8 shows that the Stokkem fan (for location cf. Fig. 6) is completely calcareous (unit I) and the calcareous material wedges out over the alluvial soils further away from the fan (succession of units VI and V). The two connections from the fan to the Geul are also distinctly visible. The fan between Schin op Geul and Oud Valkenburg in front of the 'Gerendal' (Fig. 9) shows a succession of units I, II and III from the road to the Geul. In this case progressively deeper decalcification has occurred in the older part of the sediments. Detailed augerings in the fan north-west of Etenaken (KWANTES and SNEL, 1976) revealed successive stages of deposition, separated by decalcified intervals overlying peat in the deeper subsoil. HAVINGA and VAN DEN BERG VAN SAPAROEA (1980) have presented palynological data on the age of the sediment overlying peat in the fan south of Etenaken.

Distinct fans are also found downstream of Valkenburg, but here they originate from side valleys cutting into non-calcareous Tertiary deposits, so that the actual fan is non-calcareous and not surrounded by calcareous deposits.

Fig. 6 shows the carbonate incidence associated with fans, and the difference noted above can be clearly seen.

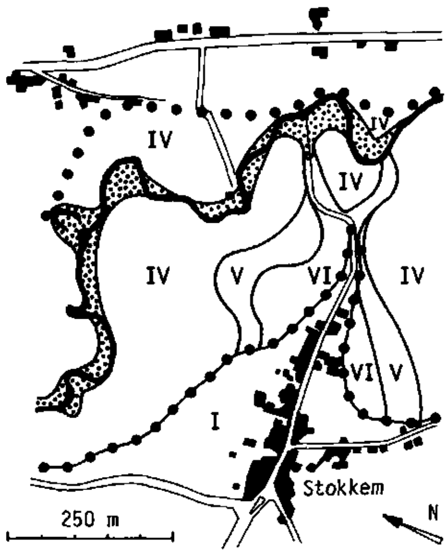
2.4. OTHER CARBONATE INCIDENCE

This includes calcareous soils at the foot of steep Cretaceous limestone slopes which are due to colluviation and normally excluded from alluvial soils.

Scattered carbonates, often in a basin position and almost exclusively corresponding to legend unit V, very often show sharp, angular boundaries on the map (Fig. 6). In most cases human influence is responsible. Farmers use limestone chips to improve the bearing capacity of the soil, as is known from information obtained in the area between Gulpen and Wijlre and between Valkenburg and St. Gerlach. Near Vroenhof the topsoil of large areas has been contaminated by transport of excavated limestone.

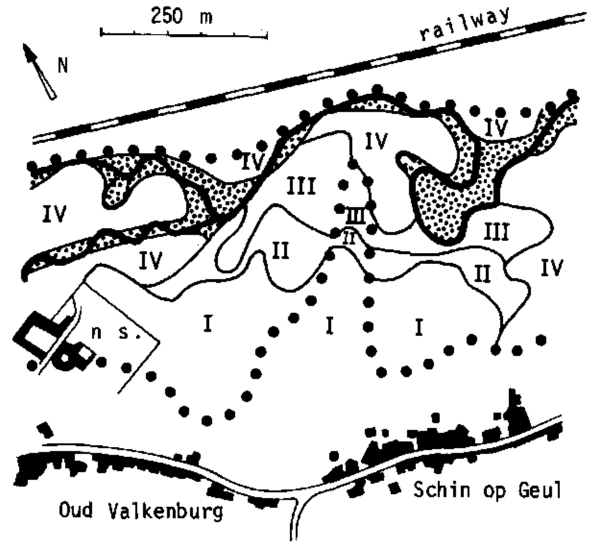
It must, however, be admitted that in some cases no satisfactory explanation can be given.

Summarizing, the incidence and distribution of carbonates linked to the sedimentation regime of the Geul can usually be satisfactorily explained by the use of the two models discussed. VAN DEN BROEK and VAN DER MAREL's statement (1964) that the levee deposits of the Geul downstream of Gulpen are calcareous needs modification in view of the variation in extent of the calcareous



I legend unit I, calcareous to 120 cm
VI legend unit VI, calcareous to 80 cm
V legend unit V, calcareous to 40 cm
IV legend unit IV, non calcareous to 120 cm
carbonate incidence associated with the Geul (legend units I,II,III)
• • boundary of alluvial soils

FIG. 8. Carbonate incidence associated with fans; the Stokkem fan.



I legend unit I, depth of decalcification 0-40 cm
II legend unit II, depth of decalcification 40-80 cm
III legend unit III, depth of decalcification 80-120 cm
IV legend unit IV, non calcareous to 120 cm
carbonate incidence associated with the Geul (legend units I,II,III)
• • boundary of alluvial soils
n.s. not surveyed

FIG. 9. Carbonate incidence associated with fans; the Gerendal fan.

part of the levee soils along the valley. Subsoil carbonates in more lightly textured deposits underlying more heavily textured deposits in the present basin positions may help to identify past changes in the river bed. Studies on the dating of the sedimentation phases (HAVINGA and VAN DEN BERG VAN SAPAROEA, 1980) are needed to ascertain the decalcification rate with the use of such modern methods as those described by LEEDER (1975), SALOMONS (1975) and SALOMONS and MOOK (1976).

Another important part of the carbonate incidence can be linked to the presence of fans in front of dry valleys cutting into Cretaceous limestone.

Most of the other carbonate occurrence can be attributed to the human influence responsible for the calcareous topsoil.

3. ACKNOWLEDGEMENTS

I gratefully acknowledge the contributions made by the students KWANTES-DORREPAAL, SNEL, BROEKHUIZEN, VAN HEMMEN, BALTISSEN, DE BOO, OOMEN and VAN DER ZEE, who carried out the detailed investigations needed to check the models described.

I would also like to thank my colleagues for the stimulating discussions on the proposed models and their constructive criticism of earlier drafts of this paper.

4. SUMMARY

Very detailed field research showed that the incidence and distribution of carbonates in the fluvial soils of the meander belt of the river Geul could be explained by the use of two models.

In the simple model the pattern of distribution of carbonates in inner bends of arcuate bodies with a progressively deeper incidence of carbonates according to their distance from the river corresponds to the accretion of an inner bend followed by time-dependent decalcification.

In the interference model the pattern of distribution of carbonates is complicated by changes in the river bed inside the meander belt. The distribution patterns observed can be explained by reconstructing the sedimentation sequence and using the simple model.

The more heavily textured transitional and basin deposits are non-calcareous as a result of synsedimentary decalcification. This enables us to distinguish sedimentation phases, likewise on the basis of carbonate incidence. Evidence of former river systems, sometimes situated in a basin position with respect to the present course of the river (buried levees), is provided by the incidence of

carbonates in the deeper subsoil in lightly textured deposits underlying non-calcareous, more heavily textured deposits.

One peculiar feature is the large areas of carbonates found irrespective of their levee or basin position and associated with fans along the valley border in front of dry valleys cutting into Cretaceous limestone.

It is hoped that the ideas put forward in this paper may throw more light on the little understood complex incidence and distribution of carbonates in the meander belts of the large rivers of the Netherlands.

5. SAMENVATTING

VOORKOMEN EN VERBREIDING VAN CARBONATEN IN DE GRONDEN VAN DE MEANDERENDE GEUL

Het voorkomen en de verbreiding van carbonaten in de fluviatiele gronden van de meandergordel van de Geul kan verklaard worden door gebruik te maken van twee modellen, zoals is gebleken uit zeer gedetailleerd veldonderzoek.

In het eenvoudige model laat het distributiepatroon van de carbonaten in binnenbochten een schilvormige opeenvolging zien, waarbij de diepte van voorkomen van de carbonaten toeneemt met de afstand tot de rivier. Dit patroon is in overeenstemming met de laterale sedimentatie van een binnenbocht, gekoppeld aan een in de tijd voortschrijdende ontkalking.

In het interactiemodel wordt het patroon ingewikkelder door stroomverleggingen binnen de meandergordel. Niettemin kan men de waargenomen patronen verklaren door een reconstructie van de sedimentatiegeschiedenis, waarna het eenvoudige model weer kan worden toegepast.

De in kompositie en in overgangspositie afgezette lutumrijkere gronden zijn kalkloos tengevolge van synsedimentaire ontkalking. Dit biedt de mogelijkheid om ook op basis van kalkhoudendheid sedimentatiefasen te onderscheiden. Het voorkomen van carbonaten in de diepere ondergrond in lichtere afzettingen gelegen onder zwaardere kalkloze afzettingen (begraven oeverwallen), is een aanwijzing voor voormalige stroomsystemen op plaatsen die soms in kompositie liggen ten opzichte van de huidige rivierloop.

Een bijzonderheid zijn de grote oppervlakken kalkhoudende gronden, die onafhankelijk van stroomrug- of kompositie voorkomen, en die samenhangen met colluviumtongen voor droge dalen, ingesneden in de kalksteenafzettingen uit het Krijt.

Hopelijk kunnen de hier gepresenteerde modellen een bijdrage leveren tot de ontrafeling van de momenteel nog weinig begrepen complexiteit van het kalkvoorkomen in de meandergordel van de grote rivieren van Nederland.

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