

PALYNOLOGY IN THE STUDY OF PRESENT-DAY HILLSLOPE DEVELOPMENT

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"Much of geomorphology is stratigraphic geology" Luna B. Leopold, M. Gordon Wolman and John P. Miller (1964).

ABSTRACT

It is pointed out that in measuring current geomorphological processes, which in general act either extremely slowly or, if more catastrophic in nature, at long intervals, knowledge of the recent geomorphological history is essential. This is particularly necessary, if the outcome of the measurements have to serve as a basis for prognosis, because an extrapolation of measurements alone is subject to a high degree of uncertainty. In the area near Bavigne (Luxembourg), where present-day displacements of slope material are measured, loamy materials covering the slopes appear often to contain pollen in appreciable amounts. Pollen diagrams constructed from this sort of material show a considerable agreement with the corresponding sections of reference diagrams prepared from alluvial deposits. The disturbance of the pollen stratification by the decay of included contemporaneous pollen combined with a supply of younger pollen, which is considered to be common in sandy soils, apparently has been equally effective in the alluvial fills and in the soils developed in the slope-covering materials. Hence, the disturbance must have been of a similar order of magnitude in the alluvial as well as in the slope materials. The present authors therefore consider the palynological analysis under certain circumstances as an appropriate technique for collecting the necessary information in regolith materials. The data obtained suggest that pollen analysis of these materials, in conjunction with lithological and pedological field evidence, not only may be used to date events, to which slope materials have been subjected in the recent past, but also to contribute to their reconstruction.

INTRODUCTION

During the last three decades a trend towards an increasing emphasis on dynamic geomorphology has occurred and at present it is an integral part of this scientific discipline. Part of this tendency has been a recognition that an increase in our knowledge of geomorphogenetic events is necessary for the practical and scientific development of geomorphology. A correct recognition and explanation of the processes involved in the formation of relief and of their

relationships to landforms and relevant materials, constitutes the principal objective of "dynamical geomorphology" (Dylik, 1957). It has long been evident that the study of present-day landforms and processes principally must contribute to this purpose.

The term hillslope development is used here to refer to the development of subaerial slopes of erosional origin, so that this term thus indicates a geomorphological process. Up to the application of general systems theory to geomorphology (Strahler, 1952), geomorphic processes were defined as those physical and chemical actions that effect and affect the earth's surficial forms. From the abstract nature of this definition, being otherwise completely in agreement with the character of traditional geomorphology, it followed as a matter of course that there was a confusing variation in the use of terms by which geomorphic processes were indicated. This confusion came partly, as Thornbury (1954) states, from differences in opinion as to what has to be included in a certain process and also from carelessness in thinking and writing, but the basic cause was and still is the complexity of the majority of processes distinguished in geomorphology. The introduction of systems theory to geomorphology has not brought any change in this respect. A geomorphic process may now be defined within the context of a geomorphological system, but a like circumscription has no greater scientific content nor does it prevent confusion in terminology.

In reality, the effects produced by geomorphological processes are the cumulative results of numerous physical, chemical and biological micro-events operating on an immense number of levels. It is due to the incomplete knowledge of the number, rates, periods, intensities and interactions of these individual events and to the unfamiliarity with their actions with respect to geomorphogenetically relevant materials and environments, that geomorphic processes are so poorly understood. For this reason, and also because in geomorphology as well as in more practical human activities, form and properties of the earth's surface in the first place are involved, it seems reasonable to denominate

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these processes for the time being simply according to their observable effects on the ground surface.

Otherwise, it is often seriously doubted that our knowledge of these individual micro-events will ever be sufficient to deduce from them geomorphological phenomena. Consequently, the view that landscapes manifest a tendency towards a mean condition of forms being statistically recognizable, has been seized and has led to the introduction of methods to express quantitatively variables which are considered to be relevant. This may be an effective way to describe landform geometry and its changes, but it has led temporarily to an overemphasizing of the "timeless" approach.

Fortunately, it was realized very early that it is undesirable and unnecessary to exclude time from the consideration of landforms and morphogenetic processes (Schumm and Lichty, 1965, Howard, 1965). Whether the aim is a better understanding of the processes or to predict future changes and forms in landscapes, knowledge of especially the recent past remains indispensable. Any geomorphic system, no matter to what extent it may be limited in space and time, ultimately consists of objects not only having a historical nature, but also of objects related in a way that is historically determined. Thus, a prognosis of future changes — being considered as the characteristic of an advanced science — can never be based on the outcomes of present-day measurements only, even when these have been made over a timespan of many years.

It is recognized that a historical reconstruction is bound to be patchy and incomplete. Nevertheless, it is fortunate that the information about the most relevant changes, with regard to the present and possible future geomorphological developments (i.e. those of the recent past) is generally to be found not so much in the geometric properties of the landforms themselves as in the materials covering and surrounding them. Various properties, features and distributions of these rock materials may reflect, along various lines, how they came into being, to what sort of alteration they have been subjected, whether or not they have been displaced, whether these shifts took place under high- or low-energy conditions, etc., and in this way the landscape dynamics of the recent past may be more or less revealed.

On landforms of an erosional nature. e.g. slopes, these materials usually form a discontinuous and scanty blanket of rock debris, which in addition is continually exposed to the actions of flora and fauna. Therefore it remains always a serious difficulty to put geomorphologically important occurrences, inferred from the study of these slope rock materials, into a precise historical framework.

The only solution is to treat these slope materials in a stratigraphic manner, although they may in themselves seem to be unsuitable for this. Butler (1959) has developed an approach based on the evidence of buried soils, which are interpreted in terms of periodic phenomena. He assumes that slopes have been subjected to an alternation of stable and unstable phases. During the former soil formation occurs,

and available rock debris is not transported downslope. During the subsequent unstable phase, the soils are truncated by downslope movement of the rock debris or buried by this material. In the next stable phase soils develop again, etc. Butler consequently considers slope materials as a blanket of successive depositional layers.

Of course there are many sites on slopes showing such a gain or loss of material, but it may be doubted whether these gains and losses will always occur as rigidly and regularly as assumed by Butler. The main disadvantage, however, remains that this approach alone does not provide sufficient data to allow an exact dating of the various phases. This is a prerequisite if a reconstruction of the immediate past has to serve as a background for measurements of present-day movements of slope materials.

Attempts to acquire these necessary complementary data by pollen analysis of slope materials, are reported in this paper. The present authors are fully aware of the difficulties that are involved in view of the materials under discussion and the conclusions must therefore be regarded as tentative. Nevertheless, the results obtained thus far are rather promising.

ELABORATION OF THE PROBLEM

Fieldwork with educational and research aims is carried out by staff and students of the Laboratory of Physical Geography and Soil Science, University of Amsterdam, in Luxembourg. In the Oesling, especially in the surroundings of the Esch sur Sûre reservoir (fig. 1), part of the work centres upon problems of present-day slope development. Consequently, much attention is given here to the study of slope materials, soil water chemistry, infiltration, runoff, sediment discharge in stream channels, valley fills, etc. The area is situated on the northern side of the anticline of Givonne (Lucius, 1957) and underlain by rocks of Lower Devonian age consisting mainly of quartzitic sandstones, quartz phyllites and slates. The landscape geometry is characterized by level summits at heights between 450 and 500 m, bordered by slopes with gentle upper and commonly steep lower parts. As to the theories about the genesis of this Oesling surface, the reader is referred to Lucius (1957), Hermans (1955) and Picket (1960).

Preliminary results from an upper part of the Birbaach catchment have been published already (Imeson and Jungorius 1974). These results suggest that the sediment discharge of a second order tributary of the Birbaach and the rate of removal of material from its valley-side slopes are both low. The ubiquitous presence of acid brown forest soils, the development of which is believed to be due to a high degree of landscape stability during most of the Holocene, is considered by these authors as supporting evidence for the inferred present landscape stability.

However, from an investigation of Heuertz and Heyart (1966), it is known that since 2600 B.P. an alluvial

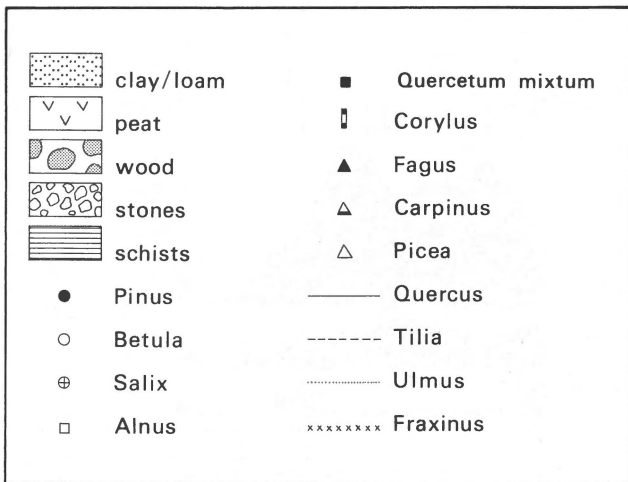


Fig. 2
Symbols used in the pollen diagrams.

deposit of five meters has been laid down in the valley of the Alzette between Pettange and Mersch (Gutland). Field observations and pollen analysis on the accumulated material in a small Oesling valley nearby the Birbaach catchment, suggest a similar age for the top part of the alluvium (see pollen diagram III in fig. 5). This indicates that during the Subatlantic in any case the natural balance was such that some of the material, supplied from the hillslopes, was left behind in the valleys. For the moment we leave aside the question whether it is desirable to speak of landscape stability during the Holocene when a filling up of the valleys is still occurring. Being cut when the channel-forming discharge was much greater, the valleys were apparently too voluminous for the conditions predominating in the Subatlantic.

A more urgent question is whether this stability of landscape implies stability of slope form, which would imply that the slope form remained unaltered throughout the Holocene. Considering the period of time involved and the existing landscape geometry, which still shows abundant relics from previous, cold period conditions, an affirmative answer seems obvious. The Holocene does not outnumber 10,000 years, a timespan that scarcely may cause a substantial change of slope forms, especially as the present area has been wooded and subjected to temperate humid climates for the most part of the Holocene (see pollen diagram I in fig. 3).

On many slope sites, however, the development of the loose materials, as seen from their profile characteristics in pits and bore holes, strongly suggests that gains and losses of material have taken place in the immediate past. In spite of the shallowness of the slope material cover, evidence of both denudation and accumulation in one exposure is not uncommon. It is clear that the inferred gains and losses within the slope-covering materials may be important with respect to

the recent evolution of these slope sites, but also that it is difficult to evaluate their significance in relation to the development of the slope profile forms. Knowledge about their spatial distribution, possibly combined with observed gains and losses at the present surface, on different slope parts would certainly provide valuable indications. Mapping of these features, however, only makes sense when among other things, some unanimity exists concerning their ages. This, because neither "stratigraphical breaks" nor "accumulations" on different or equal slope positions are a priori contemporaneous, even when they seem to be underlain by similar parts of the regolith.

It is already known that certain slope materials, being clearly recognized in the field as colluvial deposits, may contain sufficient pollen to be extracted for analysis. From the results that are discussed in this paper it appears that the amount of pollen found in differently classified slope materials may also be large enough for this purpose and this may provide a means not only to estimate or measure the age of the events on the slopes, but also for their correlation.

In the project mentioned above, the present writers have started to study the alluvial infills. In this study pollen is used as a stratigraphic tool, hence some pollen diagrams from the area are available. As these diagrams are together rather consistent they may serve as a reference for the palynological data obtained from the slope materials. These reference diagrams will be discussed first.

REFERENCE DIAGRAMS

Three alluvial profiles will be discussed. The first one (diagram I in fig. 3) is situated in the valley of the Roudbaach near Pratz (see fig. 1a) at an altitude of 190 meter and is thought to give a general reflection of the regional development of the vegetation. The second and third (diagram II and III in fig. 4 and 5) are located in the valley of the Dirbaach at altitudes of 375 and 355 meter (fig. 1b). This stream debouches into the Esch sur Sûre reservoir, near Bavigne, just as the Birbaach, and these profiles are consequently considered to reflect more the development in the area of investigation. The diagrams have been constructed according to Iversen.

Diagram 1. This diagram exhibits the evolution during the Late Dryas and the Holocene. The right hand side column shows the non-arboreal pollen and spores. Very high percentages of *Alnus* are found in the Holocene part, which indicates that during that period the vegetation in the valley was apparently an *Alnetum*. The occurrence of *Alnus* is confined to wet places, hence his component has probably not formed part of the vegetation on the adjacent slopes. In order to get a clearer picture of the changes in composition of the trees on the slopes, the diagram has also been constructed excluding the non-arboreal pollen and *Alnus* from the pollen sum.

1) Late Dryas (zone III). The material at a depth of about 190 cm was formed in the Late Dryas, being characterized

by high percentages of the non-arboreal pollen including *Artemisia*, *Helianthemum*, *Sanguisorba* and *Thalictrum*.

The transition to the Postglacial is shown by a decrease of the herbaceous species while *Pinus* increases.

- 2) Preboreal (Zone IV). A threefold division is possible. Firstly the Friesland oscillation during which the climate improves and the trees increase to 65%. Secondly, the Piotino oscillation which shows a drop in the percentages of *Pinus* together with an increase in those of *Betula*.

Radiocarbon dating at a depth of 175 cm gave a result of 9235 ± 80 B.P. (GRN 6945). This result agrees both with the dating of the Piotino oscillation in the Vorderrhein Valley and in the Lucomagno Region by Muller (1972), as well as with that found in the valley of the Little Nethe (Belgium) by M u n a u t and P a u l i s s e n (1973). Finally, a phase with a pollen suite which resembles more or less that of the Friesland oscillation and consequently points to an amelioration of the climate.

- 3) Boreal (Zone V). The transition Preboreal – Boreal is characterized by a rise of the curve of *Corylus*, *Ulmus* is represented already by a continuous curve.

- 4) Atlantic (Zone VI/VII). As beyond the depth of about 150 cm *Quercus*, *Tilia* and *Alnus* appear and extend, the boundary between Boreal and Atlantic has been placed at this depth.

- 5) Subboreal (Zone VIII). The lower limit of the Subboreal has been drawn at a depth of about 90 cm because of the commencement of the uninterrupted curve of *Fagus* and the slight decrease shown by the curve of *Ulmus*. According to a radiocarbon dating (GRN-6944), peat at the depth of about 55 cm appears to be 2815 ± 55 years old.

- 6) Subatlantic (Zone IX, Xa and Xb). The presence of *Carpinus*, *Fagus* and the decreased content of *Quercus* and *Tilia* form the outstanding features of the subatlantic deposits. The commencement of zone IX is generally placed before the first sharp increase of *Fagus* which is dated at about 100 years A.D. The continuous curve of *Carpinus* starts about the height of this *Fagus* maximum and is also found in pollen diagrams published earlier from this region (D r i c o t, 1960; M u l l e n d e r s and K n o p, 1962; D a m b l o n, 1969, 1970). Immediately after the *Fagus* maximum a strong progress of the cultivated and ruderal plants (Cerealia, *Fagopyrum*, *Artemisia*, *Chenopodiaceae*, *Plantago*, *Rumex*) occurs, which is considered as the begin of zone Xa. According to D r i c o t (1960) the sharp increase of the Cerealia found on the Plateau des Tailles, Belgium, must be dated at 1325 A.D. *Fagopyrum* has been introduced in Europe after 1400 A.D. (S l i c h e r v a n B a t h, 1960). The boundary between zone Xa and Xb is drawn at the depth of 5 cm where the curve of *Picea* starts and the *Pinus* curve exhibits a small increase due to the plantations carried out during the administration of Maria Theresia.

Diagram II This diagram covers the history of the vegetation

in the upper part of the Dirbaach Valley from the end of the Subboreal to the present time. It exhibits a considerable conformity with the corresponding section of diagram I.

- 1) Subboreal (Zone VIII). The boundary between the Subboreal and the Subatlantic is located at 90 cm as at this depth *Tilia* decreases in combination with an increase of *Fagus*. Moreover, the amount of non-arboreal pollen is increasing at the same depth.

- 2) Subatlantic (Zone IX, Xa and Xb). The pollen composition reflects the human occupation of this area. The gradual rise of non-arboreal pollen clearly coincides with a decrease in *Quercus* and the progress of *Rumex*, *Plantago*, *Compositae* and *Gramineae* indicates that the land was cleared for grazing. At a depth of 50 cm a slight enlargement of the oak forests seems to have taken place synchronously with a decline in the curves of the non-arboreal pollen. Subsequently, however, a strong decrease in *Quercus* occurred accompanied by an advance of *Alnus*. The boundary between zone IX and zone Xa is found at 30 cm. It is evident that the land has been extensively cleared. The commencement and rise of the curves of Cerealia, *Fagopyrum* and *Centaurea*, however, indicate that this now has been done for agriculture. The lower limit of zone Xb is again characterized by the appearance of *Picea* and the increase of *Pinus* at a depth of 6 cm.

Diagram III The core, from which the findings are represented in this diagram, is made up of mineral material entirely, being in contrast to those cores from which diagram I and II have been prepared. Only part of the Subatlantic is covered. Below a depth of 55 cm the deposit is a mixing of silty clay and angular gravels with enclosed wood fragments. A radiocarbon dating carried out on a piece of branch yielded a result of 1175 ± 45 B.P. (GRN – 6946). The boundary between zone IX and zone Xa is thought to be at a depth of about 32 cm. Here, the herbaceous plants gain their maximal extension, *Plantago*, *Rumex* and Cerealia show a slight increase and the intersection of the curves of *Alnus* and *Quercus* occurs. Compared with diagram II, the increase in cultivated plants and especially in Cerealia, is substantially less strongly marked. It seems obvious to assume that this may be related to lithologic differences of the cores. The lower limit of zone Xb is localized again by the appearance of *Picea* and the rise of *Pinus*.

SOME PALYNOLOGICAL DATA OBTAINED FROM SLOPE MATERIALS

As opposed to rock materials formed by long-term sedimentation in subaqueous environments, the regolith on slopes will probably offer more difficulties, when its pollen content is used for stratigraphic purposes. Compared with real sediments the mantle of rock debris is a poorly-realized product of nature. It may, of course, be possible that the

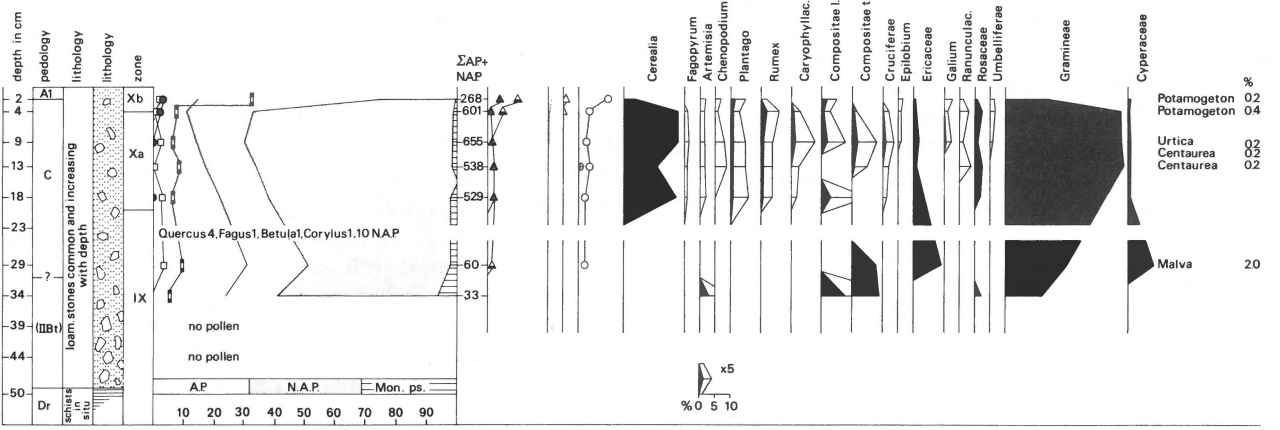
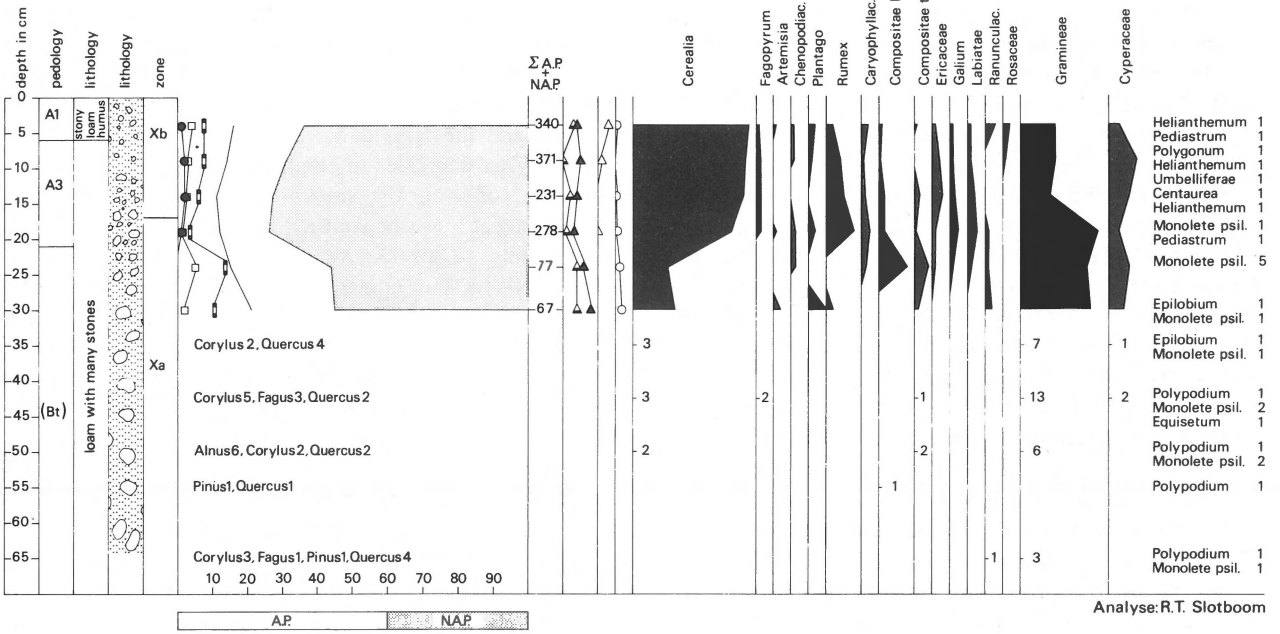


Fig. 6
 a Pollendiagram IV derived from the analysis of slope material; present vegetation: *Quercus* with *Cramineae*, *Rubus* and *Tilia*; slope angle: 6°; altitude: 455 metres.
 b Pollendiagram V of slope material; present vegetation: *Quercus* with *Gramineae*; slope angle: 16°30'; altitude: 425 metres.

pollen distribution in real sediments is subjected to changes. But, as far the present authors are aware of, it is generally assumed that the displacements of the pollen grains are negligible and that the presently found distribution can be considered more or less similar to the synsedimentary one. Rock materials on slopes are in a completely different position. They still have not found their ultimate place in the current sedimentary cycle and, especially when shallow, they suffer continually from the influence of fauna and flora. Their occurrence at the very surface of the earth makes them

susceptible to continuous chemical and physical actions, to (differential) displacements and to soil formation. As a consequence the pollen suite might be expected to show clearly these disturbing influences, to say nothing of the effect of overrepresentation. In figures 6, 7 and 8 the diagrams prepared of some 'cores' of slope materials are presented together with the observed lithological and pedological characteristics. The materials for the pollendiagrams VII, VIII and IX with the lithological and pedological characteristics were provided by Mr. Kwaad and

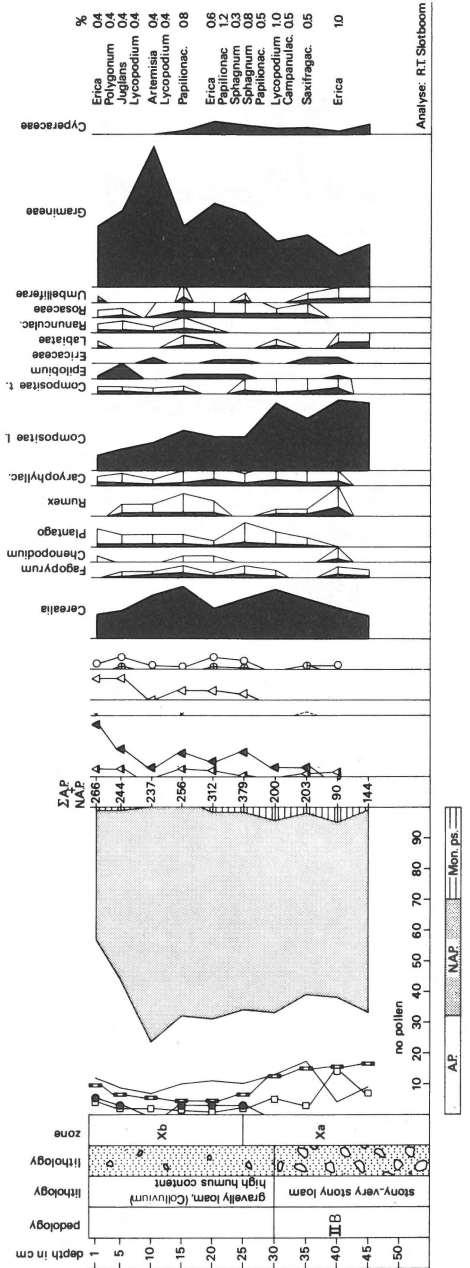
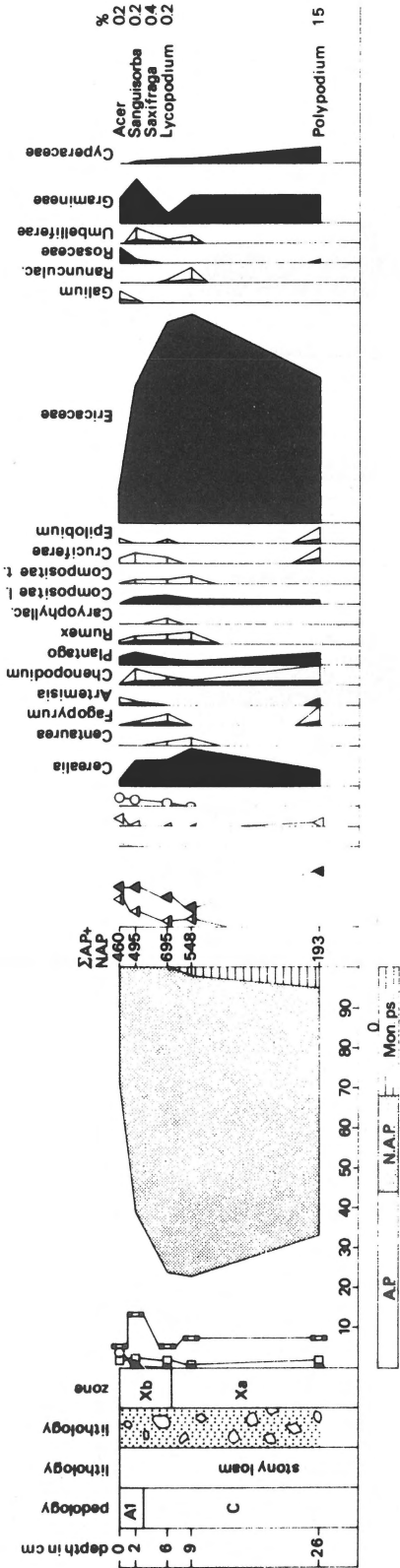


Fig. 7
 a Pollendiagram VI of slope material; present vegetation: *Quercus*, *Fagus*, *Carpinus*, *Picea* with *Vaccinium myrtillus* and *Deschampsia flexuosa*; slope angle: 28°; altitude: 379 metres. Note the abundant presence of *Ericaceae*.
 b Pollendiagram VII of slope material; present vegetation: *Picea*; slope angle: 6°; altitude: 490 metres.

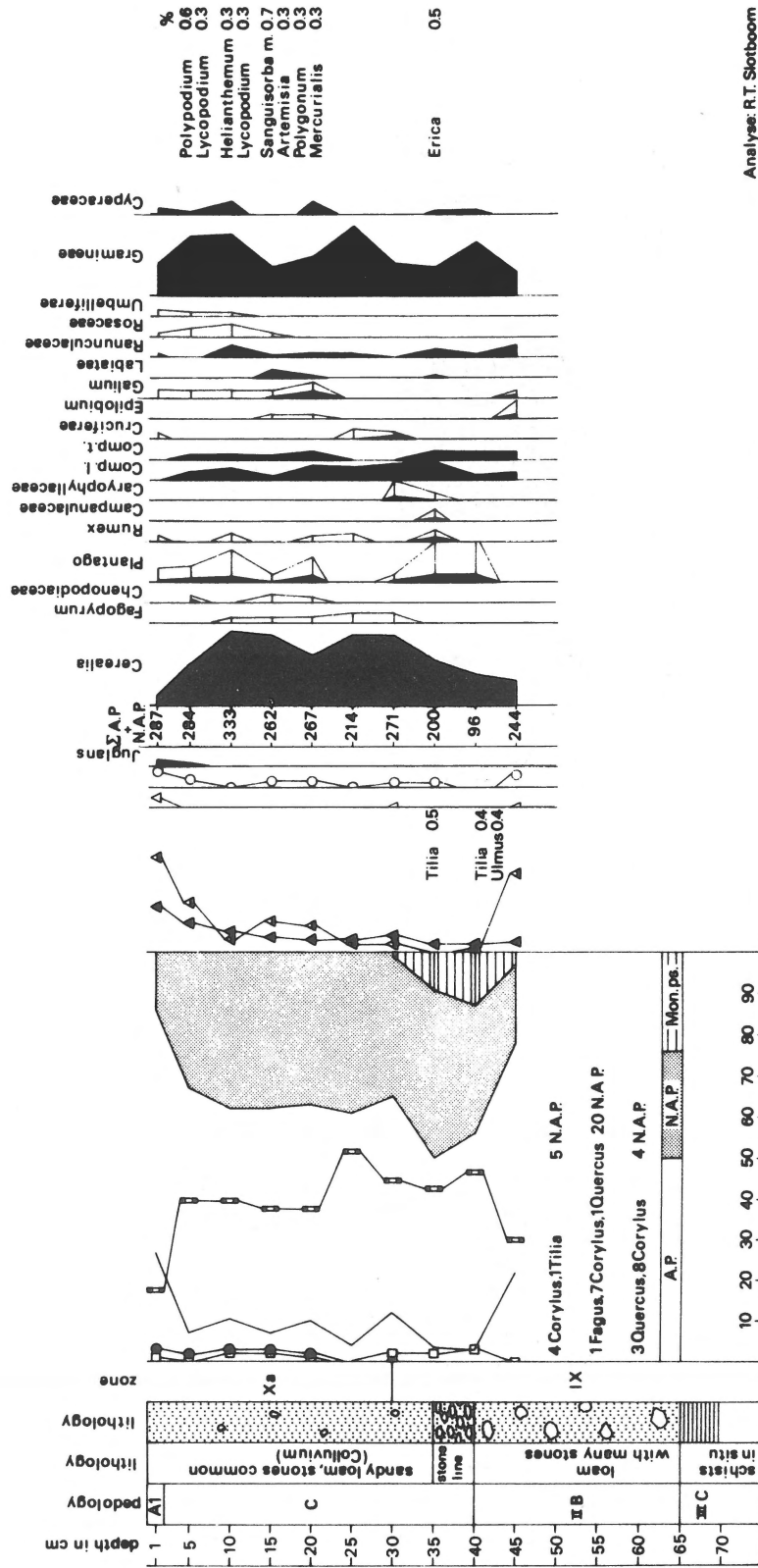
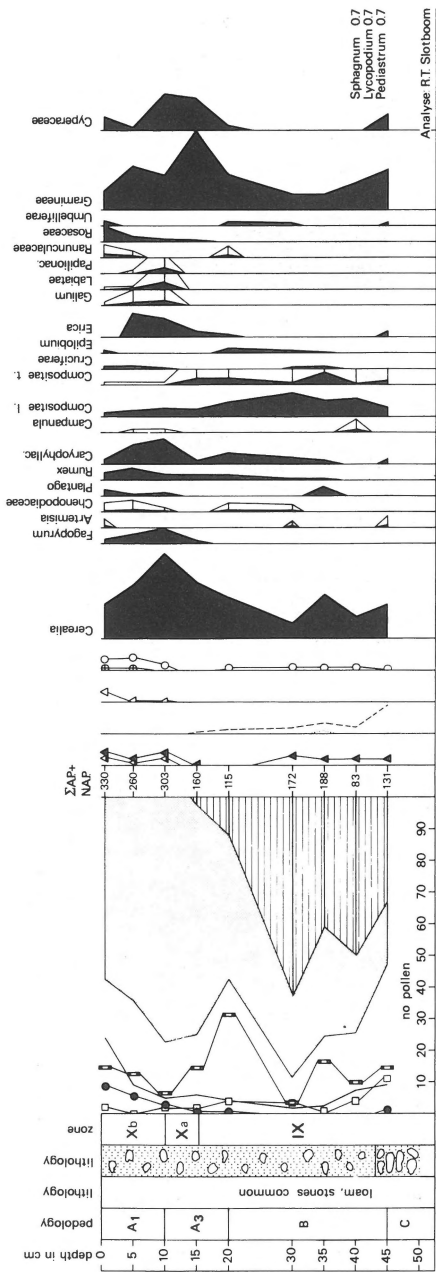


Fig. 8
 a Pollendiagram VIII of slope material; present vegetation: *Quercus* and *Pinus* with *Rubus*; slope angle: $5^{\circ}30'$; altitude: about 460 metres.
 b Pollendiagram IX of slope materials; present vegetation: *Quercus* and *Fagus*; slope angle: 14° ; altitude: about 450 metres. Note the absence of Xb. Apparently this site is now subjected to denudation after being an accumulation site since about the beginning of zone Xa.

Mr. Mücher (publication in preparation). It is conspicuous that in spite of the disturbing effects mentioned above, the results show a sequence of vegetation that is more or less similar to that found in the alluvial deposits. The diagrams cover the last part of the subatlantic history of vegetation. The criteria for locating the boundaries between the zones IX, Xa and Xb can be taken without difficulty from the data provided by the slope materials. The lower limit of zone Xa could be established on the ground of the advance of *Cerealia* and the introduction of *Fagopyrum*, the boundary between Xa and Xb is located there, where *Picea* starts and *Pinus* extends. *Tilia* may be found in those diagrams where zone IX is present but, contrary to the reference diagrams, this species seems to be lacking in the zones Xa and Xb. *Centaurea* is another plant species that is hardly found in these zones, while it may be further noticed that, again compared with the reference diagrams, the amount of *Monolete psilatae* is small. The subatlantic spectra indicate that on the slopes the same situation prevailed as in the valleys. The woods were open and consisted mainly of oaks, beeches, birches and hazelnut shrubs, the latter probably occurring especially at the borders of the forests and the clearings. Pines and spruces formed a more important part of the vegetation only after 1820 A.D. This is all rather surprising and the question arises whether this may be considered as reflecting the sensitivity of palynological analysis for stratigraphic work in this sort of material.

Havinga (1962) has stated that the distribution of pollen in soils developed in sands, gives no clues with respect to the time of deposition of the sand. In his opinion the pollen pattern in sandy soils is largely a superimposed feature caused by the decay of its original pollen content and a subsequent supply of younger pollen by infiltration. His view consequently implies a stable surface. Munaut (1967) has pointed out that the rate of migration to which pollen in the soils are subjected, is especially dependent on the intensity of the microbiological processes and that the infiltration of pollen is caused by percolating water. Therefore, Guillet (1970, 1971a, 1971b), who found the palynologically recorded history in a 50 cm thick acid brown forest soil to correspond with the same vegetation history in the uppermost 30 cm of a very nearby podsol, attaches much weight to the sort of humus of the soil. When mull is present, the migration of the pollen grains should be considerably faster than when the soil is covered by a mor layer. According to Guillet, this explains the paradoxically slow migration of pollen in podsoles and podsolized soils compared with that in acid brown forest soils. Otherwise, this author believes that homogenisation takes place not on a scale, sufficient to include whole soil profiles, but more on a scale of a decimetre.

An application of Havinga's interpretation to the present diagrams encounters serious difficulties. The soils have been diagnosed as acid brown forest soils (Imeson and Jungorius, 1974) being a soil type that, due to strong microbiological activities, is supposed to be subjected to an

intense homogenisation. In the view of Havinga, this should result in a thoroughly mixing of the enclosed pollen suite attended with its decay and followed by a supply of a regular younger pollen suite during the gradual degradation to podsolized soils. When the present findings should indeed be the combined outcome of the processes as envisaged by Havinga, the presented profiles must be supposed to have completed to a greater or lesser extent the stage of soil degradation. In the field, however, neither the present authors nor their colleagues have found on the slopes any sign of podsolisation. On the contrary, biological activity is still highly perceptible. In any case, no podsolisation has been observed in the presented profiles. But this implies according to Havinga that in these soils a thoroughly mixed association of pollen must be found at present. The succeeding vegetations, however, known from the reference diagrams, can also be reconstructed from the results gained by a palynological analysis of the slope materials, indicating that a similar palynological stratification still exists. The course of the different species curves exhibit scarcely the influence of homogenisation on the pattern of pollen distribution. Successive spectra showing more or less parallel courses of some curves are occasionally found (see diagram IX, fig. 8b), but they appear to derive from material recognised in the field as colluvium. So this phenomenon may be attributed as well to a comparatively fast deposition. The present findings seem to match more the conception of Guillet (1970, 1971a, 1971b). This author, who rejected the homogenisation of pollen caused by biological actions in soils, has also found the undisturbed stratification of pollen in brown forest soils. He attributes this to the great intensity of the microbiological destruction of aggregates containing pollen and to a fast, subsequent infiltration of the liberated pollen. In this way, the successive spectra in such soils will reflect only a short, recent part of the vegetation history. But also in this view, the distribution of pollen remains a superimposed feature, although considerably less outspoken, because the timespan between the moment that rock material is about to be available for soil formation and the moment at which it has taken in a pollen suite, is much shorter.

RELATIONSHIPS BETWEEN PALYNOLOGICAL AND PROFILE DATA

The usefulness of palynological data may be greatly enlarged when they are considered together with pedological and lithological characteristics observed in the field. The present characteristics, simplified in the pollen diagrams, are based on field descriptions of several persons. Lithologically the slope material, being a loam with included rock fragments, is rather monotonous. The amount and size of these fragments usually increase with depth although sudden changes occur. Not uncommonly a concentration of fragments gives rise to a stone layer. The sand and clay content

of the loam occasionally vary. Slope materials identified in the field as colluvium frequently show, besides a high humus content, a low density of comparatively small rock fragments. From the pedological descriptions it is evident that we are dealing with complex soils showing frequently a rather weak development of the horizons in the upper part of the solum. Apart from a thin A₁ horizon, the B horizon, if present, seems to be the only well-marked soil layer. Soil layers, however, designated as B horizons or subhorizons, vary strongly from place to place. When a layer is distinguished as II B horizon, it is because a sharp transition or even a disappearance of the well-known properties (colour, consistency, structure, clay concentration) upwards through the profile, coincided with a clear lithological boundary (see diagram VII, fig. 7b). Evidently, this soil layer formed part of a soil now eroded down to this horizon, and consequently it can be considered as a truncated, buried soil. However, sharp lithological boundaries are mostly lacking and the properties mentioned less pronounced. If also gradual decrease in these less strongly marked properties upwards in a profile occurs, the soil layer has been indicated simply as B with potential letter and number subscripts. Field observations suggest that the material of the overlying, weakly differentiated horizons may partly be made up of remnants of B horizons. Even when such a clear horizon at the base of the soil profile is lacking, the overlying soil layers may contain these relics.

Palynologically this B horizon also appears to be distinct from the others. The number of included pollen grains may range between zero and the number commonly found in the other horizons, though mostly they fall short of this number. It is, however, highly remarkable that the pollen content is nil or negligibly small when particularly one typical B horizon feature is fully developed: real argillic B horizons (Bt or IIBt) are very probably completely devoid of pollen (see diagram IV and V in fig. 6). Finally, it appears that diagrams, prepared from profiles with a distinct B horizon at the base, exhibit sometimes, with decreasing depth, a regular or irregular increase in the number of pollen grains per spectrum (see diagram V, fig. 6b).

EVALUATION OF THE FINDINGS

In attempting to evaluate the collected data, the following must be borne in mind:

- 1) At the investigated sites in the Oesling area, slope materials contain apparently sufficient pollen for analysis to enable the reconstruction of the history of the vegetation in the recent past.
- 2) The regolithic materials show a palynological stratification similar to that found in nearby valley deposits. The conformity is indeed only confined to the zones IX, Xa and Xb of the Subatlantic, but this is, because up until now no spectra from earlier zones have been recovered from the shallow regolith.
- 3) A particular soil layer, the B horizon, characterized

especially by a high concentration of illuviated clay and a blocky structure (Bt), forms an exception. The number of pollen, found in this argillic horizon, may be nil or much lower than in the remaining soil horizons. Commonly, this horizon is underlain by the hard rock.

- 4) The impression has been gained that there is a relationship between the content of pollen and the degree in which these horizon characteristics are expressed. If the horizon in question evidently is encountered in situ, which is inferred from a very marked clay concentration, structure and colour, the majority of its spectra show no pollen or only a few tens of arboreal and non-arboreal specimens. If the field evidence shows a lesser expression of the horizon characteristics, generally more pollen are found in the spectra.
- 5) The other, weakly developed soil layers often hold remnants of the Bt horizon. The concentration of these relics generally decreases towards the surface.

It was particularly the fact that the pollen stratification of historically known succeeding vegetations in an acid brown forest soil was well preserved, that led Guillet (1971b) to reject the idea of biological homogenisation over the whole depth of soil profiles and to conclude that homogenisation of the pollen by biological activity does not seem to exist. On the basis of the results presented in this paper, the present authors find it difficult to believe that pollen in such considerable amounts will be moved downwards in this type of soil profile. It may thus be asked, why succeeding changes of vegetations have been so regularly recorded in the soil profiles. Does the water percolate to a lesser depth in proportion as the change is more recent? Will in future the introduction of *Picea*, which now occurs in all diagrams at about the same depth (only in recently colluviated materials, as diagram VII in fig. 7b shows, it may be met at somewhat lower levels), be found to run concurrently with the appearance of *Fagopyrum*? Or will at that time the arrivals of this species and *Fagus* coincide? How to explain that in alluvial deposits, which during an important part of the year are soaked with water, the pollen suite attains a sequence comparable with that found in slope material? What kind of mechanism makes pollen grains in their natural state appropriate for such a drastic downward transport in soils? Of course, displacement of pollen grains will have taken place, but in view of the present palynological results it seems reasonable to assume that these movements have occurred in a similar order of magnitude both in the alluvial as well as in the regolithic materials.

The consequences are plain. If a palynological investigation of sediments affords the means to obtain some knowledge about vegetation composition, species frequencies, climatic conditions, etc. during their deposition, in order to locate them on a time scale, this analysis may apparently also be applied with the same purpose on the present slope materials. But this implies that the present slope-covering materials at the investigated sites have not been very

stationary in the recent past. In fact they must have been more mobile than was inferred from the recognition of local colluvial accumulations and occasional stratigraphical breaks. Obviously, these phenomena reflect only local, more catastrophic, expressions of this mobility. The normal movements to which the regolithic particles have been subjected, apparently have been so slow, that their displacement and subsequent deposition left no recognizable features in the regolith, but nevertheless they must have been rapid enough to include every year the pollen rain.

As will appear in the following, this supposed continuous moving of the regolith particles seems to be consistent with the pedological characteristics encountered in the profiles. It is evident that material of fully-developed argillic B horizons contains no pollen. In itself, this is very conspicuous, as the accumulation of the clay is supposed to originate by deposition from percolating waters. The present authors are unable to account for this lack of pollen. It might be possible that the material of these horizons originated by weathering processes at the boundary between regolith and hard rock and therefore has not yet been exposed to the influences occurring at the very surface. Another possibility is that the original, contemporaneous pollen content has been destroyed during the formation of the argillic horizons. Field evidence suggests that these Bt horizons genetically are not related to the A₁ horizons i.e. they are not the results of the current soil formation, but they must have been produced during a previous one.

If we put together the results re-emphasized in the beginning of this chapter under points 1-5, a rather consistent outline of the succeeding events may be given. Somewhere in the past the formation of soils with clear Bt horizons occurred, probably over an extensive part of the considered slope area. As the development of argillic horizons seems to be favoured by a forest cover and a climate with pronounced dry seasons, it might be possible to locate this soil formation somewhere in the Subboreal. There are several reasons for this. Compared to the observable relics of the vegetation from the preceding Atlantic and subsequent Subatlantic, those from the Subboreal point to a less wet climate. It is, however, impossible to deduce from reconstructed composition of the vegetation whether this is due to a reduction or to a more unequal distribution of precipitation throughout the whole year. Further, the formation of argillic horizons has never been reported in soils of the youngest landscapes (Soil Survey Staff USA 1967). In view of the great likeness of climates in the Subatlantic and Atlantic, a large-scale development of this sort of soil horizon in the latter period seems therefore less probable. However, it may be asserted that also the Preboreal and Boreal climatic conditions might have been favourable for the genesis of this argillic horizon.

Thereafter, but perhaps also already during that soil formation, the destruction and removal of the uppermost soil horizons took place. It is up to now impossible to decide whether the intensity of these processes has been normal or

not, especially because the period of the argillic horizon formation is obscure. However, because at about 800 A.D. the nature of the infill in the Dirbaach Valley (fig. 5) and in other Oesling valleys too, underwent a sudden change — fine-grained sediments are underlain by deposits consisting mostly of coarse gravels and rock fragments — the present authors presume that in the preceding period a large, rather drastic discharge of sediment occurred. It may be quite possible that such a large removal of material from the valleys corresponded with an intensification in slope erosion, though it is uncertain if this removal immediately preceded the beginning of the Subatlantic. In any case, during zone IX of the Subatlantic, on several sites on the slopes the argillic horizon was largely removed while at other places it was still being attacked. During this destruction of the Bt horizon at the end of zone IX, the displacement of the regolithic material slowed down, but continued to be active. In terms of volume-distance of the moved material a similar reduction set in, with the result that from now on the pollen rain could be included in the continuously shifting and accumulating materials. Fragments of the eroded Bt horizon were continually incorporated in the shifting surface layer, while they increasingly diminished in size, lost their consistency and typical properties, disintegrated and became part of aggregates mainly cemented by humic material. The presence of a plain, though thin A₁ horizon at the present surface probably reflects a further slowing down after about 1800 A.D.

CONCLUDING REMARKS

Palynology has proved its usefulness in the study of depositional landforms. The present data show that it may be utilized also in the investigation of erosional landforms. The agreement between the included pollen suites in regolithic and nearby alluvial material from the Oesling, strongly suggests, that in both these materials the post-depositional disturbance of the pollen distribution may be of a similar order of magnitude. In catchment areas, where this is a wide-spread phenomenon, pollen analysis of slope materials enables to date and to correlate geomorphologically relevant features in the mantle of the slope-covering debris. In addition to this, the analysis may reveal the occurrence of small-scale movements of slope materials which left no perceptible marks in the profile. Particularly the establishment of such imperceptible material movements from the immediate past and their duration, may be of outstanding significance for the extrapolation of the rates of presently operating processes.

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