A MICROMORPHOLOGICAL STUDY OF SOME SOILS AND SLOPE DEPOSITS IN THE LUXEMBOURG ARDENNES NEAR WILTZ IN VIEW OF THE LATEST PHASES OF LANDSCAPE DEVELOPMENT

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ABSTRACT

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The paper gives a detailed description of the micromorphological properties of the soils, found beneath forest on four different landscape units south west of Wiltz in the Luxembourg Ardennes. These landscape units are: plateau tops, gentle upper slopes, steep lower slopes and dry valley bottoms. The systematic description of the soils is followed by an interpretation of the observed characteristics in terms of their implications for the history of the landscape. The soils on the plateau tops and the steep lower slopes are young, having developed during the last 150 years consequent upon reafforestations after a period with rather severe soil erosion, tentatively dated from some time before 1400 A. D. until 1800 A. D. The soils on the upper slopes and in the dry valleys are polygenetic. They show a truncated and buried argillic horizon, which is a remnant of the soil profile, formed in Würm glacial mass wasting deposits during the Atlantic and/or Subboreal. The Btb horizon is overlain by a slope deposit, which originated as a consequence of late medieval and later forest clearings. Biologic homogenization is excluded

as a cause of the horizons, overlying the Btb horizon on the upper slopes, on several grounds. The part of the profile above the Btb horizon exhibits a pollen stratification, similar to that found in peat and alluvial deposits from the same area. It shows the Subatlantic pollen zones IX, Xa and Xb. In one profile *Fagopyrum* (buckwheat), which was introduced in the area about 1400 A. D., was found to start at a depth of 70 cm, indicating that the uppermost 70 cm of the deposit were formed after 1400 A. D. Soil erosion has markedly slowed down since about 1800 A. D. due to reafforestations. At present the slow normal rate of erosion is found beneath forest.

INTRODUCTION

This paper is an interdisciplinary study in regional geomorphology and regional paleopedology. It describes an investigation of the loose surface material, covering the slopes of the Luxembourg Ardennes, southwest of Wiltz (Fig. 1). In its composition and stratification this mantle of surface material reflects the environmental conditions, under which it was formed. It is the purpose of this paper to reconstruct these conditions and to track down any changes therein. This will be done by a detailed analysis of the micromorphological properties of the surface material. Besides the nature and origin of the surface soil, which has a polygenetic character, as will be shown in this paper, the time of formation of its different geogenetic horizons will be discussed. To that end pollen analytical data will be used.

This study has an exploratory character on the one hand; on the other hand it can help clarify the issue of soil erosion attendant on medieval deforestations in the Oesling, which is a matter of dispute (see review of literature).

The area, where the present study was carried out, is situated south west of Wiltz in the Oesling, the northern part of Luxembourg (Fig. 1). The Oesling forms part of the Ardennes.

Geologically, the Oesling is an area underlain by strongly folded Paleozoic rocks of Lower Devonian age (Lucius, 1950). The rocks exhibit a low degree of metamorphism, the most common rock type being the so called « schistes » or « Schiefer ». In this paper they will be designated as shales, because,

although they possess slaty cleavage, the degree of metamorphism is too low to call them slates. Besides this argillaceous rock type, arenaceous types occur, including quartzites and quartzitic sandstones, intercalated in the shales. The folding of the rocks took place during the Hercynian orogeny. Three major tectonic units can be distinguished in the Oesling : the Bastagne anticlinorium in the north, the Givonne anticlinorium in the south and the Wiltz synclinorium in between them (Lucius, 1950).

Morphologically, the Oesling belongs to an old planation surface, which was uplifted and thereupon dissected by rivers during the Quaternary. Because the Bastogne and Givonne anticlinoria are composed of very resistant rocks, showing only slight variations in hardness, major parts of the uplifted planation surface were saved from dissection in those areas. In the Wiltz synclinorium, to which the area, dealt with in this paper belongs, relatively soft shales abound and because of this the uplifted planation surface was more fully dissected here. This part of the Oesling shows many small plateaus at an altitude of 470 to 490 m, from which long, gentle slopes lead to steeply incised valleys with maximum valley side slope angles of over 30 degrees. Part of the valleys are dry.

Pedologically, the Oesling is characterized by the prevalence of dystrochrepts (dystric cambisols).

Brief review of the literature on the Oesling

The first one to describe and analyze the mantle of loose material in the Oesling in detail was Hermans (1955). Fig. 2 has been taken from his work. Note that the relief in this figure is strongly exaggerated as a consequence of differences in vertical and horizontal scale. The slope in fact is not steeper than 2 to 3 degrees. Hermans claims that, apart from local influences (notably the presence of bands of resistant rock in the subsoil), the idealized cross section in Fig. 2 is the key to any profile one may find in the Oesling. It shows a slope leading from a level top towards a depression. On the top only a thin layer of very stony loam occurs. On the slope the following layers are encountered from the surface downward :

1. Colluvial loam (limon colluvial). The colour of this loamy deposit is brown, it contains few angular rock fragments and it can reach a thickness of more than 1 metre. Hermans considers it to be the product of slope wash. The time of formation of the colluvial loam is not specified.

2. A layer of friable, brown loam, containing many, only slightly weathered, angular rock fragments. The fresh rock fragments in this layer are supposed to have been derived from the « erosion point » (see Fig. 2), from where they should have spread over the slope. It is not clear, whether Hermans ascribes this layer to periglacial (Pleistocene) or to Holocene conditions.

3. A solifluction layer, composed of compact, brown loam with many, strongly weathered shale fragments, which can easily be broken with the hand. This horizon has a slightly higher clay content than the overlying loam. The surface of this layer is often wavy, ascribed to cryoturbation by Hermans. In many instances the solifluction layer shows signs of gleying (gray and brown spots). The layer should have been formed under Pleistocene periglacial conditions.

4. A zone showing crocheting (Hakenwerfe).

5. Bed rock (folded and fractured Devonian shales, sandstones and quartzitic sandstones).

According to Hermans the above sequence widely occurs on the gentle slopes of the northern part of the Oesling. In the southern part of the Oesling, with its steeper, more strongly denuded slopes, the compact solifluction layer is less ubiquitous. There it only occurs in places.

Piket (1960) gives a much more detailed subdivision of the landscape than Hermans. Piket distinguishes the following elements in the morphology of the Oesling (from high to low) :

— peneplain remnants
— pediment remnants
— pediment valleys
— dry valleys (dellen)
— valley heads
— remnants of river terraces
— steep valley side slopes
— valley floors.

The first three are considered by Piket as relict forms from the Tertiary. The other features of the landscape originated during the Quaternary as a consequence of tectonic uplift, leading to incision of the rivers and periglacial climatic conditions, causing solifluction. All of these landscape elements are covered with a layer of loose material with characteristic properties. We will not enter into a detailed discussion of the nature of the regolith on the various landscape elements distinguished by Piket, but merely give Piket's main conclusions :

1. The peneplain remnants are covered with a layer of weathering material in situ, which can reach a thickness of more than 5 metres. It should have been formed under the warm-humid conditions of the lower and middle-Pliocene. This finding strongly contradicts Hermans' view, that the higher parts of the Oesling only carry a very thin layer of weathering material and that certainly no relicts from Tertiary soils occur on these high plateaus.

2. In the regolith on the pediment remnants, in the pediment valleys, the dellen, the valley heads and on the river terraces two layers can be distinguished :

a) A relatively fine grained top layer with a texture, ranging from heavy loam (pediment valleys) to brown, sandy loam with some angular rock fragments (pediment remnants, dellen, valley heads, terrace remnants). Piket considers this top layer as a slope deposit formed by creep and slope wash during the Holocene. Part of it may have been formed as a result of soil erosion, which, according to Piket, has been important in the Oesling during the Middle Ages and the 16th, 17th and 18th century as a consequence of extensive deforestations.

b) The top layer covers a layer of very stony loam, containing large, angular, hardly weathered rock fragments. The coarse layer is considered by Piket as formed by Pleistocene (Würm) solifluction.

3. On the steep valley side slopes only a thin layer of recent rock waste occurs. It consists of loose, unsorted, sandy loam with many, little weathered, angular rock fragments. The lower part of the profile contains more stones than the upper part. Piket considers this slope material partly as weathering ma-

terial in situ and partly as material having been moved downslope by creep and slope wash.

4. The sediment covering the valley floor generally consists of heavy clay, overlying gravel.

Verhoef (1966), in this work on the border zone between the Oesling and the Gutland (the southern part of Luxembourg), mentions the presence of two types of slope deposits that are attributable to periglacial denudation : a type showing no stratification (solifluction material) and a type showing distinct bedding parallel to the surface upon which it rests (« grèzes litées »). In both types the bulk of the material is made up of tightly packed rock fragments, either in random orientation (solifluction deposits) or arranged in thin beds (« grèzes litées »). Superimposed upon the periglacial deposits Late Holocene colluvial accumulations occur, recognizable by pieces of charcoal, a finer texture than the solifluction material and the presence of volcanic heavy minerals deposited during the Allerod period. The Holocene slope deposits are attributed by Verhoef to accelerated erosion following deforestation for various purposes (charcoal birning, oak bark cutting for the leather industry, agriculture) during the Neolithicum, the Roman colonisation period, the Middle Ages and the 19th century (Verhoef, 1966, p. 459). According to Verhoef the alluvium in many valleys also has resulted from accelerated erosion caused by human interference.

The authors, mentioned so far, agree upon the presence in the Oesling of a relatively coarse solifluction layer, covered by a less coarse, younger layer, termed « limon colluvial » by Hermans (1955), « postglacial creep and slopewash deposits » by Piket (1960) and « Late Holocene colluvium » by Verhoef (1966).

Imeson and Jungerius (1974) in a discussion of present day landscape forming conditions in the Luxembourg Ardennes arrive at the conclusion, that erosion under forest is slow at present. This conclusion is based upon measurements of precipitation, overland flow, sediment load of the river, erosion pins and soil aggregate stability in a small river catchment, south west of Wiltz. In the second part of their paper the authors present an interpretation of the soils of the area to the effect, that erosion has been slow

during most of the Holocene too, because «as long as the natural vegetation remains, complete soil profiles developed under deciduous forest during the Holocene can be found everywhere, even on the steepest slopes». They claim, that wherever forest was replaced by cultivated land, erosion may have removed much of the original cambisols. However, nowhere has the increase of soil erosion been catastrophic. The differentiation of the soil profile on the upper slopes in the area south west of Wiltz into a relatively loose, stony surface soil and a much more compact and more stony subsoil is attributed by Imeson and Jungerius to in situ homogenization of the profille. In other words, the top layer was not formed by deposition of material brought down from upslope, but by vertical movements within the solifluction matérial, which still forms the subsoil of the profille. The subsoil shows evidence of a phase of weathering, which, according to Imeson and Jungerius, must predate the last glaciation, because the material shows signs of post-decompositional disruption by solifluction and because it contains papulles, which are derived from a type of clay cutans, that is known to occur in paleosols of Eemian age.

Riezebos and Slotboom (1974) studied the alluvial deposits in the same general area, that is dealt with in this paper. They found, that before 800 A. D. (radio carbon dating) deposition of coarse gravels and rock fragments took place in the valley of the Dirbaach, which may correspond with an intensification in slope erosion prior to 800 A. D. The part of the alluvium in the Dirbaach valley, younger than 800 A. D. is fine grained, which is considered by Riezebos and Slotboom as pointing towards a slowing down of slope rosion after 800 A. D., whereas a further slowing down is assumed from about 1800 A. D.

METHODS

As the presence and nature of buried soils, pedorelicts, erosional discordances etc. in slope deposits, reflecting the alternation of phases of landscape stability and landcape instabillity, are most surely recognized by microscopic examination of the surface material, the present study is chiefly based on micromorphological evidence. Especially the presence of (buried) horizons with clay illuviation can only be esta-

blished with certainty in the laboratory. Both claycontent and the presence (or absence) of illuviation cutans can easily be misjudged in the field (Blume and Schlichting, 1959; Bouman and van Schuylenborgh, 1969).

Palynological investigation of the slope material was performed in order to obtain information on the age of the deposits.

Undisturbed samples and samples for pollen analysis were taken from selected profiles on the various landscape units of the area (« tops », « gentle upper slope », « steep lower slope », « dry valley floor »). The locations of the profile pits were chosen after a preliminary survey of the slopes, to be studied, by means of augering.

For the description of the profiles in the field the FAO guidelines for soil profile description and the Munsell Soil Color Charts were used. For the classification of the soils the Soil Taxonomy (1973) was used. The classification according to the FAO-Unesco Soil Map of the World (1974) is given in brackets. The colours were determined of the moist soil. No calcium carbonate was present in the soils, $pHCaCl_2$ varying from 3 to 5.

From the undisturbed samples mammoth sized sections were prepared according to the methods described by Altemüller (1956, 1962) and Jongerius and Heintzberger (1963). Brewer's (1964) terminology was used for the microscopic description of the thin sections, supplemented with terms introduced by Bal (1973), Barratt (1969), Kubiena (1938, 1948), the Laboratory of Regional Soil Science of the Agricultural State University of Wegeningen and Mücher et al. (1972).

On several thin sections of the Btb horizon point counts were made, using the Blaschke ocular (Blaschke, 1967), in order to get an estimate of the amount of illuviated clay.

In all 11 profiles were sampled, distributed over the various landscape units as follows (see Figs 1 and 3) :

1. Top profiles, located on the highest parts of the numerous small plateaus in the area (Bremich 1, Groendchen 8, Nothum 2).

2. Upper slope profiles, situated on the long gentle slopes leading from the plateau tops toward the steeply incised valleys (Berlé 1, Haarts 2, Nothum 1).

3. A lower slope profile, situated on a steep valley side slope (Nothum 3).

4. A profile on a (structurally controlled ?) narrow, terracelike break in a steep lower slope (Breimicht).

5. Profiles located near or at the centre of two dry valleys (Haarts 1, Groendchen 7, Groendchen 9).

All profiles, with the exception of Berlé 1 (arable land), were taken from wooded sites. From every landscape unit one characteristic profile is described in an appendix.

DISCUSSION AND CONCLUSIONS

Areal differentiation of the profiles

Plateau tops

The soils on the plateau summits are shallow. Most extremely they consist of a dark brown A1 horizon, directly overlying hardly weathered bedrock in situ. More often, however, a thin cambic B horizon is present below the A1 horizon. Because of their shallowness and poor development the soils on the plateau tops are considered as young. They are classified as lithic umbric dystrochrepts and umbric dystrochrepts (ranker and dystric cambisols).

Upper slopes

On the upper slopes deeper soils occur than on the tops. They consist of a very stony and very compact lower part and a less stony and looser upper part. The boundary between the lower and upper part of the profile is sharp. The lower part of the profile coincides with a well developed IIBtb horizon, characterized by the presence of medium to very thick illuviation ferriargillans. The less stony upper part of the profile exhibits an A1—A3-cambic B horizon differentiation.

The soils on the upper slopes raise the question, whether a change in conditions has to be assumed in order to explain the observed profile characteristics and, if so, what the nature of this change may have been and when it may have taken place. Imeson and Jungerius (1974) put forward the idea, that the differences between the lower and upper part of the profile, called subsoil and surface soil respectively by them, should be attributed to in situ homogenization of the soil, by

which they understand the turn-over of soil material through the action of soil fauna and roots. They write, that it is conceivable, that the differences between the subsoil and the surface soil are caused by downslope creep of the surface soil over the subsoil, but that such movement has not yet been established. It is implicit in their discussion of the soils on the upper slopes, that the argillic horiozn in the subsoil was formed prior to the last glaciation and that the surface soil originated under conditions, which remained unchanged throughout the Holocene. The present authors feel, that the Btb horizon in the subsoil is of Holocene age and that during the Holocene a change in conditions occurred, which led to the formation of the surface soil. We shall consider the important question of the time of formation of the Btb horizon in a later section. At this point we would like to examine the problem of the nature and origin of the surface soil and the material, constituting it.

There is no doubt, that the material, constituting the surface soil, was not derived by simple weathering in situ of the underlying shale. After being released from the hard rock by weathering an appreciable mixing and/or movement of the detritus must have occurred. This is apparent from the following combination of micromorphological feactures (Mücher, 1974), observed in the surface soil :

a) the presence of many sharply bounded and mostly (sub) — rounded lithorelicts with colours in incident light, varying from grey, yellow, orange, brown to red. There various forms or stages of iron segregation, exhibited by intermixed fragments of the same rock type, are not to be expected in the case of an in situ origin of the detritus. The presence of fresh (grey) rock fragments, which must have been loosened recently, and the general lack of weathering rims indicate a recent displacement of the soil material.

b) the presence of sharply bounded and (sub)rounded ferric nodules next to diffuse ferric nodules, the latter apparently formed in situ.

c) the presence of pedorelicts in the form of some papules and a few para-aggregates.

d) the presence of charcoal fragments of varying dimensions. Questions are, what may have caused the mixing of the

material constituting the surface soil, and when the displacement took place, or the last phase of it, as the material of the surface soil may have gone through more than one period of instability (see section on chronology).

The main arguments, presented by Imeson and Jungerius (1974) in favour of an origin of the surface soil by homogenization, are :

a) The occurrence on the level plateau summits and on the steep lower slopes of basically the same soil profiles as on the upper slopes, with a total lack of correlation under forest between slope angle and the depth of the surface soil.

b) The nature of the boundary between the surface soil and the subsoil, which, though abrupt, is irregular. In some profiles the A3 horizon penetrates into the subsoil in pipelike protuberances and pockets.

c) The presence throughout the surface soil of a characteristic association of volcanic heavy minerals, which was spread over the area during the Allerod as a consequence of volcanic eruptions in the Eifel (Jungerius, 1958; Hulshof et al., 1968; Jungerius and Mücher, 1970a, 1970b).

The present authors would like to reconsider these arguments and to propose an alternative interpretation of the observations in order to make them fit in with the general picture of a postglacial period of increased slope erosion in the area of study, for which more evidence will be presented below.

Ad a. It should be noted, that on the level plateau summits spotwise AC-profiles occur with an A1 horizon not exceeding 20 cm (compare profile Breimicht 1), whereas on the rest of the plateau top area more fully developed soil profiles occur, resembling the profiles on the upper slopes. It could be argued, that the patches of land with an AC-profile are the only true summits in the area and that the rest of the general plateau top area should be included in the gentle upper slope class. By definition the level summit land unit class was meant to include terrain with slope angles up to 2°. Perhaps this has caused the real relationships to be obscured. A detailed mapping of a few selected plateaus would be needed to sort this matter out.

Ad b. As to the irregular topography of the boundary between the surface soil and the subsoil it can be said, that in

the centre of the valleys in the area of study profiles occur with a top layer of more than 40 cm dark brown colluvium, which exhibits the same irregular lower boundary. On examining the pollen in one of the pockets protruding into the IIBtb horizon of a dry valley soil, it appeared to differ appreciably from the pollen in the colluvium and to be virtually identical to that of the O horizon. Therefore we consider the irregularities of the lower boundary of the surface soil as a feature of biologic origin, that is younger than and consequently superposed upon an originally smoother lower boundary.

Ad c. Regarding the presence of volcanic minerals to a depth of several tens of centimeters in the soil, it can be remarked that, at least for sloping sites, the evidence is inconclusive since both homogenization and lateral supply can account for this fact.

These alternative interpretations of some facts of observation gain in probability, when taken together with the considerations to follow.

What exactly must be understood by homogenization and what effects must be attributed to it ? The precise character of homogenization was deliberately left open by Imeson and Jungerius (1974), though they refer to it as in situ process ob biologic origin. If so, then the process may be ascribed the effects of the processes of faunalpedoturbation and floralpedoturbation subtypes of the process of pedoturbation (Hole, 1961), which is one of the causes of regrouping phenomena in soils (Jongerius, 1970). Regrouping is defined by Jongerius as including « all changes in the mutual arrangement of solid soil components in the pedon, caused by natural processes or by human activity, in so far that they — at least as concerns the mineral components — are not a consequence of enrichment from outside the pedon or of transformations in situ ». It is within the limits of this general definition, that we shall use the term homogenization in this paper. The term pedoturbation was introduced by Hole (1961) as a synonym for « soil mixing ». It represents a local cyclic movement of soil materials, which inhibits the formation of soil horizons or which disturbs them. Faunalpedoturbation refers to the mixing of soil by animals and floralpedoturbation to soil mixing by plants. Jongerius (1970) explains, that mixing can take place within

one horizon or that material from various horizons may be mixed. In the last case and also when there is a question of discontinuance of the sedimentary lamination one speaks of homogenization (Hoeksema, 1953).

There is another cause of regrouping phenomena in soils, which should be considered for the soils on the upper slopes, viz. the process of organic sorting (Ollier, 1969). Organic sorting, instead of disturbing or mixing soil horizons, creates a new soil horizon on top of the original soil surface. Profiles, for which organic sorting is put forward as a mechanism to explain certain characteristics, e. g. stone lines, are reported from the tropics, where they are attributed to the activity of termites (Nye, 1955; Williams, 1968). For the profiles, discussed in this paper, earthworms moles and voles might be assumed to fulfil the role of the tropical termites. The possible sorting effect of earthworms on the soil was demonstrated at Rothamsted (Russell, 1961, table 10).

We shall consider both possibilities (pedoturbation and organic sorting) for the soils on the upper slopes.

Pedoturbation. A critical point in this respect is the nature and origin of the horizon differentiation in the soils on the upper slopes. Three horizons can be distinguished in the surface soil, as exemplified by profile Nothum 1 (see Appendix). From the surface downward : 0—10 cm, a dark brown A1 horizon, rich in organic matter; 10—40 cm, a brown A3 horizon, containing less organic matter; 40—50 cm, an iron stained, yellowish brown cambic B horizon. It is difficult to see how this differentiation, especially the cambic B horizon, fits in with the homogenization idea. It could be argued, that homogenization is not as important today as it was once and that at present differentiating processes predominate, or that at present homogenization only occurs in the A1 and A3 horizon. However, if important biologic pedoturbation is (was) to occur, one would expect this to show in the thin sections of the horizon(s) in question. Jongerius (1970) lists the following morphological effects and features of faunalpedoturbation (terrestric) : a) disturbance of layers, b) mull, c) iso-, aggro-, fragmo-, striotubules, d) channels with vermicutans, e) fecal pellets, f) papules, g) loss of textural B morphology (blocky—crumbly). In fact, channels and pedotubules are rare in the A3

horizon Most fecal pellets, instead of single, are (strongly) welded; they do not contain any recognizable plant remains, but consist of completely decomposed organic matter; they do not exhibit a vertical zonation by type, as would be expected from the preference of certain species of the soil microfauna to live at certain depths. Only very few papules were observed, also near the boundary with the underlying IIBtb horizon, where most papules would be expected. Besides, charcoal fragments and melanons (Bal, 1973), too large for fecal pellets, were found to abound throughout the surface soil.

Organic sorting. The micromorphological evidence does not seem to point to a substantial increase in depth of the surface soil by organic sorting. Moles (or voles) do in fact bring material from the B and C horizon to the soil surface in the area of study, as was established by Imeson (1975). However, no B or C-material was observed in the thin sections of the Al horizons studied by the present authors. This is taken to indicate, that either the excavation of soil material by burrowing rodents proceeds at a very slow rate and/or the material carried to the surface is removed quasi-instantaneously by subsequent erosion of the animal mounds. The latter process can be observed to place at present under forest in the area of study (Imeson, 1975; Imeson and Kwaad, 1975). It may contribute to the formation of a colluvial deposit at the foot of of the slope. Erosion of mole hills, however, is not thought to have been a very important factor in the formation of the surface soil on the upper slopes. Something more drastic must have occurred.

As pedoturbation and organic sorting do not seem to be the main processes, leading to the formation of the surface soil, the present authors consider the part of the profile, overlying the IIBtb horizon on the upper slopes, as a slope deposit, originally rich in organic matter and containing fecal pellets. After deposition mineralization of the organic matter from below occurred, which process is favoured by the moisture conditions at some depth in the soil (Minderman, 1961). The part of the slope deposit, which has lost its organic matter, now forms the cambic B horizon of the surface soil, whereas the part of the colluvium, which still contains its

organis matter, constitutes the A3 horizon. The A1 horizon is enriched in organic matter by soil formation in situ, indicating that at present soil formation is more important than colluviation on the upper slopes. The structural characteristics, exhibited by the B and A3 horizon, may be inherited features, as experiments with splash boards in the area of study show, that raindrop impact can cause the movement of soil aggregates up to 4 mm (Kwaad, 1977).

In the part of the soil profile, overlying the IIBtb horizon on the upper slopes, pollen is present, showing a zonation similar to that found in a peat diagram and several alluvial diagrams from the same area (Riezebos and Slotboom, 1974, and this paper). This remarkable conformity in pollen stratification between the upper slope soils and reference diagrams is considered as evidence of a sedimentary character of the upper slope soils. Pollen may become incorporated in the soil by homogenization (Havinga, 1962), and Imeson (1975) claims, that the rate at which soil material is carried to the surface by burrowing rodents in the area of study is not dissimilar to the rate at which pollen is buried. Riezebos and Slotboom (1974) however, following Guillet (1970, 1971), conclude, that in this case homogenization is not the most likely cause of the observed pollen zonation.

In view of the preceding the soils on the upper slopes are classified as thapto-ochraqualfic umbric dystrochrepts (dystric cambisols, overlying truncated gleyic luvisols).

Lower slopes

On the steep lower slopes no signs of a IIBtb horizon were found, whereas the IIBtb horizon is clearly expressed again in the dry valleys. We assume, that at one time during the Holocene (see section on chronology of events) a soil with an argillic horizon was wide-spread in the area, including the lower slopes. Today a soil with an A1—A3-cambic B horizon differentiation, to be classified as an umbric dystrochrept (dystric cambisol), can be observed on the lower slopes. We tentatively consider this profile as essentially similar in nature and origin to the surface soil on the upper slopes, the difference between the upper slopes and the steep lower slopes being that on the upper slopes the original alfisol (luvisol) was

truncated down to the IIBtb horizon, whereas on the lower slopes the argillic horizon was removed completely. In both cases the truncated profile was then covered with colluvium, which accounts for the presence of charcoal fragments and many mullicol and argillicol aggregates in the A3 and cambic B horizon.

Alternatively, the cambic B horizon on the steep lower slopes could be considered as the equivalent in time of the argillic horizon on the upper slopes and in the dry valleys, implying that there never was an argillic horizon on the lower slopes. In this view, the original cambisol was truncated down to the B horizon, followed after reafforestation by the formation of a thin A1 horizon in the truncated B horizon. This interpretation does not account for the presence of charcoal fragments and paraaggregates in the cambic B horizon.

Dry valleys

In the centre of the dry valleys the deepest soils of the area occur. They are clearly polygenetic. Essentially, they resemble the soils on the upper slopes. The exhibit a truncated IIIBtb horizon, developed in older slope deposits, on top of which a stony, dark brown colluvium occurs, rich in organic matter. The colluvium often has a stone line at its base, which is devoid of organic matter and in profile Groendchen 7 showed signs of weak clay illuviation. Contratry to the soils on the upper slopes, no A1 horizon was observed in the dry valleys, only an O horizon on top of the dark brown colluvium. Apparently, there is a difference between the upper slopes and the dry valleys in the rate of colluviation compared to the rate of soil formation, the extreme case being that colluviation has ceased altogether on the upper slopes, whereas it is still active on the fairly steep side slopes of the dry valleys.

The sedimentary character of the part of the profile, overlying the IIIBtb horizon, is confirmed by the pollen zonation it displays (see Fig. 7), which is similar to the zonation found in reference diagrams.

Profile Breimicht 2, located on a narrow terracelike break in a steep lower slope, is virually identical with the soils in the dry valleys, except that it has an A1 horizon in the colluvium.

The IIIBtb horizon shows red-gray colour mottling, due to pseudo-gleying. The soils in the dry valleys are classified as thapto-ochraqualfic udorthents (dystric regosols, overlying truncated gleyic luvisols).

Arable land

Mention should be made here of the occurrence in the area of study of another type of colluvium. The colluvial deposits, discussed so far, all occur beneath woodland (at least today it is woodland). The colour is dark brown (7. 5YR 4/2) and the maximum depth is about 70 cm. In dry valleys beneath present day arable land, however, a different type of colluvium occurs, colour yellowish brown (10YR 5/4) and maximum depth over 2 metres. In the one profile studied so far (Berlé 1) it appeared to overly, like in the case of the « woodland » colluvium, a truncated IIBtb horizon. It contains less and smaller stones (up to 4 cm) than the « woodland » colluvium and is remarkably uniform in colour and texture over its entire depth of more than 2 m. Systematic research of this colluvium is in progress, on which we will report in a separate paper.

Tentative chronology of events

When dealing with buried soils in a certain area, Butler's K-cycle idea presents an appropriate guiding principle in arranging one's observations and deductions on the history of the area (Butler, 1959). On applying Butler's approach to the area of study, the following periods of relative landscape instability and stability emerge from the facts of observation :

1) A cycle, during which the area was uplifted and dissected (K_{3u}), followed by weathering of the exposed rock (K_{3s}).

2) A cycle, during which the products of the preceding stable phase were subjected to intensive mass wasting processes (K_{2u}), followed by the formation of a soil with a claerly developed Btb horizon in the mass movement deposits (K_{2s}).

3) A cycle, during which soil erosion occurred (K_{1u}), giving rise to the slope deposits, in many places overlying the

truncated Btb horizon from the K_{2s}-phase, followed by the relatively stable phase with soil formation dominating soil erosion of today (K_{1s}).

In the next three sections the time-stratigraphic position of the K_3, K_2 and K_1-cycle will be discussed together with the conditions reigning during the three cycles.

K_3-cycle

Evidence for the unstable phase of the K_3-cycle lies in the morphology of the area. It is held responsible for the origin of the main features of the relief of the area of study, more specifically for the coming into being of the valleys dissecting the otherwise rather expressionless plateaus.

Remnants of the stable phase of the K_3-cycle are still present in the soil in the form of the material constituting the mass movements deposits, which originated during the unstable phase of the K_2-cycle. Conspicuous elements of this material are numerous red rock fragments (lithorelicts), mostly smaller than 1 cm, which can readily be distinguished both macroscopically and microscopically. All that can be said, regarding the age of the K_{3s}-phase, is that it must predate the K_{2u}-phase, which is tentatively placed in the Würm glacial. So it must belong to the Eemian and/or one of the older interglacials, whereas (part of) the detritus on the upper slopes may even stem from the Tertiary.

It will be clear, that the expression K_3-cycle is used here as a collective term, embracing the effects of all cycles preceding the K_2-cycle, though strictly speaking it was only meant by Butler (1959) to include the effects of the last cycle preceding the K_2-cycle. The more remote in time the cycles are however, the more difficult it is to keep them (or their effects) apart. For the purpose of the present study it was not considered worth trying to do this.

K_2-cycle

There are several indications, that the Btb horizon, belonging, to the stable phase of the K_2-cycle was not formed in the weathering products of the K_{3s}-phase in situ. The material, in which the Btb horizon is developed, consists of shale and sandstone fragments of gravel and stone size, embedded

in a loamy matrix. The rock fragments are virtually unweathered. The loam can be scraped from their surface with a knife without touching upon the stones themselves. The same impression is gained from the thin sections. Embedded in the S-matrix sharply bounded lithorelicts occur, showing no weathering rims or zones. This mixture of unweathered rock fragments and loam can only be explained by assuming a phase (K_{2u}) of increased activity of slope processes, which must have been of the mass wasting type, considering the lack of any stratification, the large size of the rock fragments and the overall chaotic appearance of the deposit.

As the Btb horizon in the mass movement deposits is considered as post-glacial and as no indications of older phases of weathering and/or soil formation were found in the mass movement deposits, they are believed to have originated during the last glacial though sure signs of a periglacial origin, like vertically placed stones (Pissart, 1973; Vorndran, 1972) and silt cappings on the upper surfaces of the size grades larger than 1 mm (Romans, Stevens and Robertson, 1966) were not observed by us.

During the stable phase of the K_2-cycle (K_{2s}) a soil with a clearly developed Btb horizon was formed in the slope deposits of the preceding unstable phase. The percentage illuviated clay in the Btb horizon, as determined with the point count method using the Blaschke ocular, reaches values of 2.9% in profile Nothum 1 (upper slope) and 4.5% in profile Groendchen 7 (dry valley bottom). The maximum percentage encountered in the profiles studied is 7.4% in profile Haarts 1 (dry valley bottom). As these percentages are based on 1000 point counts, the absolute error of the percentages is 1—1.5% (v. d. Plas and Tobi, 1965).

The Btb horizon shows varying degrees of plasma reorientation, ranging from silasepic to omnisepic.

Several types of illuviation cutans can be distinquished, reflecting more than one phase of clay illuviation due to changing conditions during the formation of the Btb horizon. From the composition of the compound cutans it appears, though this is not always claer, that a phase giving rise to the formation of yellow, strong continuous ferriargillans was followed by a phase (or phases) with conditions less ideally

suited for clay illuviation, during which brown or dirty, weak continuous ferriargillans and matri-argillans were formed. The greater part of the illuviation cutans is found in situ, clothing the walls of channels, planes and vughs. A minor part of the cutans is deformed or even disrupted and is not associated with any void, existing at present in the soil. The disrupted illuviation cutans (papules) are of the strong continuous type. They represent an early phase of clay illuviation.

The terminus ante quem for the Btb horizon is formed by the overlying deposit, which is of Subatlantic age, as will be shown in the next section. A definitive terminus post quem is lacking, but, as the Btb horizon does not give the impression of being disturbed by gelifluction, an interglacial age is considered unlikely. This narrows the time of formation of the Btb horizon down to the Holocene, excluding the Subatlantic. Going by the climatic conditions, generally said to be favourable for clay illuviation, viz. a wet climate with a dry season (Fitzpatrick, 1971), one would be inclined to point out the Subboreal as the most probable time of formation of the Btb horizon. From loess areas, however, soils with an argillic horizon (Parabraunerden) are reported to have been formed during the Atlantic (Reuter, 1964; Smolikowá and Lozek, 1973). This would agree with Blum and Ganssen's (1972) contention that Cf-climates further clay illuviation An Atlantic and/or Subboreal age therefore seems plausible for the Btb horizon in the area of study.

The formation of the argillic horizon seems to have come to an end, not by a change in climate, but by human interference. This was the case in the loess area of Dutch South-Limburg (v. d. Broek, 1958; Bouma, Pons and Van Schuylenborgh, 1968; Mücher, 1974) and also seems to be the case in the Oesling (see next section).

K_1-cycle

The K_1-cycle started with an unstable phase (K_{1u}), during which the soil from the preceding stable phase was completely eroded (plateau tops and steep lower slopes) or truncated down to the Btb horizon and buried beneath a rather stony, organic matter containing slope deposit (upper slopes and dry valley bottoms).

The slope deposit, overlying the truncated Btb horizon on the upper slopes and in the dry valleys, asks for an explanation of its origin and a determination of its age. These questions are closely interconnected, e. g. a Holocene age would rule out a periglacial origin and vice versa.

Starting from the nature of the deposit, the following properties should be explained by any hypothesis on its origin : the presence of many stones (up to 20 cm), the lack of any stratification, the high organic matter content of the uppermost 40 cm, and the presence of a stone line at the base of the deposit (only in the dry valleys). The presence of stones and gravel, randomly embedded in a loamy matrix, reminds of a mass wasting type of deposit. Periglacial mass wasting under permafrost conditions can be excluded, however, on several grounds : the primary organic matter content of the deposit, the lack of any field evidence of periglacial conditions (vertically placed stones [Pissart, 1973. Vorndran, 1972], cryoturbation, polygon structures, frost cracks etc.) and the absence of certain micromorphological features, commonly found in frost influenced soils, like discontinuous spherical or vesicular pores, horizontally aligned silt droplets and silt cappings on the upper surfaces of sand and grit particles over 1 mm diameter (Taber, 1943; Fitzpatrick, 1956, 1971; Romans, Stevens and Robertson, 1966). This would still leave the possibility open of humid solifluction. However, mass wasting must be ruled out altogether, because the pollendiagrams of the deposit suggest a gradual incorporation by yearly increments of the pollen rain into the deposit.

Mass wasting being excluded and normal erosion being improbable, because of the stony character of the deposit, we have to resort to man as originator of the deposit. The presence of man in the area of study at the time of formation of the deposit is clearly indicated in the pollendiagrams. The decrease in arboreal pollen and the increase in non-arboreal pollen, of which cereals and other culture elements form an important part, are an unmistakable sign of the forest clearing and agricultural activities of man. Deforestation and agriculture must have created conditions, leading to a rather severe erosion of the once wooded slopes. Judging by the absence on the tops and the steep lower slopes of any remnants of the

argillic horizon, formed beneath the formerly existing forest, erosion must have been most intensive there. The eroded soil was deposited on top of the truncated soils of the upper slopes (colluvium in transit) and in the dry valleys.

The stone line at the base af the deposit in the dry valleys merits special attention. From the pollendiagrams it appears, that the Btb horizon is completely devoid of pollen, except the upper part of it, which contains pollen, showing Subatlantic spectra of zone IX. This is interpreted to mean, that during some time before the formation of the stone line agriculture was practiced on the truncated Btb horizon, by which pollen was mixed with the soil. The intensification of agriculture and/or the expansion of the arable land area from about 1400 A. D. may thereupon have given rise to slope instability, leading to the formation of a very stony slope deposit at the foot of the slope.

The less stony upper part of the slope deposit, rich in organic matter, reflects the reverting to equilibrium conditions, aided by the reafforestations of the past 150 years. The reafforestations in fact meant the onset of the stable phase of the K_1-cycle, we live in today. The processes dominating at present on the wooded slopes of the Oesling are soil formation and slow colluviation, aided by the activity of burrowing rodents, which bring mineral soil to the surface on top of the litter, where it is exposed to rainsplash erosion and frost creep (Imeson, 1975, Imeson and Kwaad, 1975; Kwaad, 1975). This state of presentday landscape stability is mirrored in the low sediment load of the rivers in the area of study (Imeson and Jungerius, 1974).

The time of formation of the deposit formed during the K_{lu} -phase has to be inferred from the pollen it contains. So far no peat has been found beneath it, nor a piece of wood in it, allowing a more reliable age determination by C-14 analysis. The pollen analysis of soils and slope deposits is still in its infancy and may show many pitfalls in the future. With this proviso pollen diagrams were prepared and interpreted of 7 profiles, 3 of which were published already by Riezebos and Slotboom (1974), viz. Nothum 1 (upper slope), Breimicht 2 (colluvium on break in lower slope) and Groendchen 9 (colluvium in dry valley). Three other diagrams are published

here : Haarts 2 (upper slope), Haarts 1 (colluvium in dry valley) and Groendchen 7 (colluvium in dry valley). See Figures 4, 5, 6 and 7. For the location of the profiles see Fig. 1.

As pointed out by Riezebos and Slotboom (1974), the slope deposits, overlying the Btb horizon, appear to exhibit the same pollen stratification as the peat and alluvial deposits in the area. This similarity is taken to indicate, that the pollen stratification in either type of material came about by the same mechanism. From this it follows, that by palynological investigation of the slope deposit some information can be obtained, regarding the composition of the vegetation and the climatic conditions at the time of formation of the deposit. Also the deposit may be placed on a time scale.

The diagrams of the figures 5, 6 and 7 cover the latter part of the Subatlantic. They exhibit the Firbas pollen zones IX, Xa and Xb. The boundaries between the three zones can be drawn without difficulty by comparison with the reference diagrams (Riezebos and Slotboom, 1974; Slotboom, in prep.). Zone IX begins shortly before the first rise of the beech *(Fagus)* at about 100 A. D.

Tilia may be found in the diagrams, where zone IX is present. The lower limit of zone Xa is drawn at the retreat of the arboreal pollen, the advance of the *Cerealia* and the introduc- of *Fagopyrum* (buckwheat) at about 1400 A. D. in the area (Slicher van Bath, 1962). The boundary between zones Xa and Xb is placed, where *Picea* (spruce) starts and *Pinus* (pine) expands. The spectra of zone Xa indicate an open landscape. Zone Xb in its high content of arboreal pollen (70 — 80%) reflects the expansion of the wood area after 1800 A. D., due to the *Picea* plantations.

Especially *Fagopyrum* is a landmark for the age determination of the slope deposits. The part of the deposit above the first appearance of buckwheat must be younger than about 1400 A. D. In profile Groendchen 7 (dry valley centre) this involves the uppermost 70 cm. A second *Fagopyrum* maximum at 30 cm depth in this profile possibly reflects the revival of the buckwheat culture at the end of the 18th century, consequent upon the high wheat prices and the appearance of the Black seab in 1775. The top 15 cm of profile Groendchen 7 must

have originated after about 1800 A. D., considering the start of the *Picea* curve at 15 cm.

Summarizing on the K_1-cycle, it can be stated that man's influence on the landscape forming processes in the area of study has been considerable during the last 2000 years. At first he created conditions, which gave rise to important movements of soil material along the claered slopes. During the past 150 years he has tried to restore the equilibrium by reaf-forestation measures.

The reconstruction of events during K_1-cycle we have tried to give here is based solely on pedological and palynological evidence. It has to be corroborated to the largest extent possible by the study of the written sources on the history of land use in Luxembourg from Roman times onward, whereas also prehistoric research into the Bronze Age and Neolithic occupation of the area by man may be of interest in this context.

Summarizing the discussion, it can be said that the present study amounts to a corrobaration of the views, expressed by Hermans (1955), Piket (1960), Verhoef (1966) and Riezebos and Slotboom (1974) on a post-glacial period with a greater intensity of the slope forming processes than we witness today. This period of increased slope erosion could be recognized as being induced by man in late-medieval time and the three centuries to follow.

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APPENDIX

SOIL DESCRIPTIONS

1) *Profile number :* Breimicht 1

Classifications : lithic umbric dystrochrept (ranker)
Location : 400 m north of a point at 1.5 km south west of Maison Schuman along road N 26 to Bavigne (see Fig. 1); ± 6 km SW of Wiltz.
Elevation : 465 m.
Land form : level summit of westward extending spur of larger plateau
Slope : 2°.
Vegetation : mixed oak-beech coppice.

Profile description (abbreviated) :

A 1 0—20 cm very dark grayish brown to dark brown (10YR 3/2-3/3) gravelly loam; many fresh angular fragments of shale and quartzitic sandstone (up to 5 cm); moderate medium crumb; abrupt smooth boundary

R 20—(50) cm olive gray (5Y 5/2), fractured bed rock in situ (shale lnd quartzitic sandstone); brown (7.5YR 4/4) loam in fissures of bed rock (up to 5 mm in width).

Micromorphological description :

A1 horizon

Lithorelicts : many, hardly weathered, gray to reddish brown shale and sandstone fragments
Humiskel : common very coarse and few medium and extremely coarse root fragments, dominantsly with birefringence
Biorelicts : common to many charcoal fragments (up to 2.1 mm)
Voids : abundant fine and medium meso compound packing voids, many fine meso skew planes, common channels (coarse meso and very fine macropores), very few coarse meso vughs and very fine macro joint craze planes, parallel to the soil surface (only in uppermost 6 cm of the horizon)
S-matrix : agglomeroplasmic related distribution
Skeleton grains : abundant silt and common very fine sand grains, dominantly quartz and mica
Plasma type : mullicol, with a silasepic plasmic fabric
Plasma reorientations : not observed
Cutans : not observed
Glaebules : few very coarse manganese nodules and very few coarse and very coarse ferric nodules with skeleton grains enclosed, both types with sharp and distinct boundaries
Pedotubules : few faint very coarse aggrotubules with sharp boundaries
Fecal pellets : abundant medium and few very coarse matric fecal pellets, often in clusters

R horizon (disturbed sample, fine earth scraped from large pieces of bed rock)

Gray, fresh shale and sandstone fragments mixed with dark brown fine soil material, showing an agglomeroplasmic related distribution. Brown argillicol with a silasepic plasmic fabric. Brown staining is mainly due to ferric iron oxyde and to a lesser extent to finely divided organic matter. Common coarse and very coarse matric fecal pellets. Plasma reorientations and cutans : not observed.

2) *Profile number :* Nothum 1

Classification : thapto-ochraqualfic umbric dystrochrept (dystric cambisol, overlying truncated gleyic luvisol)
Location : 75 m north of a point 700 m south-west of Nothum along country road to Bavigne (see Fig. 1); ± 6 km SW of Wiltz, north Luxembourg
Elevation : 485 m
Land form : north facing upper slope leading from narrow plateau spur to steep valley
Slope: 6°
Vegetation : mixed oak-beech coppice with undergrowth of blackberry

Profile description (abbreviated) :

A 1 0—12 cm dark brown (7.5YR 3/2) gravelly loam; many fresh angular shale and sandstone fragments; moderate medium crumb; clear smooth boundary
A 3 12—30 cm brown (7.5YR 4/4) gravelly loam; many fresh angular shale and sandstone fragments; weak medium crumb; clear wavy boundary
B 30—40 cm yellowish brown (10YR 5/6) gravelly loam; many fresh angular shale and sandstone fragments; weak coarse subangular blocky; friable moist; abrupt smooth boundary
II Btgb 40—50 cm light gray 2.5Y 7/2) and strong brown (7.5YR 5/6) mottled very gravelly loam; many medium prominent mottles; coarse subangular blocky; sticky; patchy thin cutans of clay minerals with iron oxides and hydroxides; very many fresh shale and sandstone fragments (up to 8 cm); abrupt smooth boundary
II C + 50 cm light gray (2.5Y 7/2) loamy gravel, few strong brown 2.5YR 5/6) mottles.

N.B. animal burrows up to 7 cm diameter, filled with brown loam, penetrate into B, II Btb and II C horizon.

NOTHUM 1

Micromorphological description :

Horizon :	A 1	A 3	B	II Btgb
Lithorelicts :	many shale and sandstone fragments (1—7 mm), fresh and with iron segregation, low and high sphericity, subangular to subrounded, no weathering rims	many rock fragments (2—10 mm), dominant shale, few sandstone, mostly with iron segregation, colours in incident light yellow, orange, bright red, no weathering rims, low and high sphericity, subrounded, sometimes rounded	many rock fragments (2—5 mm), dominantly shale, few sandstone, little weathered, low sphericity angular	horizon consists chiefly of rock fragments (5—20 mm). shale and sandstone, weakly weathered, low sphericity, subrounded; weak parallel distribution, inclined to the surface
Humiskel :	few to common coarse to extremely coarse root fragments with birefringence, few coarse red brown root fragments without birefringence	very few to few very coarse root fragments with birefringence	very few coarse and very coarse root fragments with and without very weak birefringence, very few medium root fragments with birefrigence	very few very and extremely coarse rootfragments with birefringence
Biorelicts :	common charcoal fragments (up to 3.4 mm)	few charcoal fragments (coarse and very coarse sand size)	very few charcoal fragments (size of fine, medium and coarse sand)	not observed

NOTHUM 1 (CONTINUED)

Voids :	many very fine, fine and meso-macro vughs; common (medium meso) craze planes; few (very fine macro) channels	many joint craze planes (mesopores) parallel to surface (chiefly at 15—20 cm depth); many vughs (medium and coarse mesopores, very fine macropores, coarse macropores); very few channels (very coarse macropores)	many craze planes (mesopores), common vughs (fine macropores) very few channels (coarse, meso and very fine macropores), locally compound packing voids (very fine macropores)	many skew planes (micro, meso and very fine macropores), many vughs (coarse meso and medium macropores), sometimes interconnected, few channels (medium and coarse meso pores)
S-matrix :	porphyroskelic related distribution skeleton grains (silt size) closely spaced	porphyroskelic related distribution	porphyroskelic related distribution	agglomeroplasmic related distribution with very porous plasma (intrapedal voids), locally intertextic
Skeleton grain :	abundant silt and common very fine sand grains, dominantly quartz, high sphericity, subangular	abundant silt and common very fine sand grains, dominantly quartz, high and low sphericity, subangular	abundant silt and few very fine sand grains, dominantly quartz, high sphericity, subangular	common silt and very fine sand grains, dominantly quartz, high sphericity
Plasma type :	mullicol, with a silasepic plasmic fabric, dark brown in incident light, due to organic matter	dominantly mullicol, silasepic; spots of argillicol, stained by iron, in lower part of horizon	argillicol, stained brown by iron	argillicol, partly grayish, partly brownish

NOTHUM 1 (CONTINUED)

Plasma reorientations :	not observed	not observed , except in an aggregate at 23 cm depth (momasepic plasmic fabric)	fine weak insepic plasmic fabric, strong fine masepic plasmic fabric at borders of some fecal pellets	greyish plasma : strong, very coarse wavy masepic plasmic fabric (matrans?) brownish plasma : clear mosepic plasmic fabric, fine and medium around some litho-relicts : medium skel-sepic plasmic fabric.
Cutans :	not observed	not observed	on single fine illuviation (?) ferriargillan at 39 cm depth	common medium, yellow plane and channel illuviation ferriargillans, common very thick compound illuviation cutans, composed of yellow ferriargillans, alternating with grey matri-argillans, very few thick greyisch illuviation matriargillans

NOTHUM 1 (CONTINUED)

Glaebules :	very few coarse to very coarse ferric nodules with rather diffuse boundaries	very few to few coarse and very coarse brown ferric nodules with diffuse and sharp boundaries, with and without skeleton grains; very few fine strong continuous yellow argillaeous papules in an aggregate at 23 cm depth	few dark brown ferric nodules with sharp boundaries and enclosed skeleton grains (medium to very coarse); very few very coarse ferric concretions with diffuse boundaries	iron segregation requently occurs; very few strong continuous coarse papules
Pedotubules :	few very coarse (0.4 mm) ortho aggro-tubules and very few extremely coarse (2.1 mm) ortho aggrotubules	very few to few very and extremely coarse ortho-aggrotubules	one very coarse ortho-striotubule at 38 cm depth	one meta tubule (3 cm, partly aggro-partly isotubule, material derived from overlying horizon
Fecal pellets :	many to abundant, single, sometimes welded, medium matric fecal pellets; few to common, mostly welded, very and extremily coarse (up to 1.3 mm) matric fecal pellets	many brown and dark brown medium matric fecal pellets, single, sometimes welded, in clusters and in channels; few very coarse or extremely coarse matric fecal pellets strongly welded	locally very coarse matric fecal pellets, welded	not observed

3) *Profile number :* Nothum 3

Classification : umbric dystrochrept (dystric cambisol)
Location : 50 soth of a point at 1.4 km southwest of Maison Schuman along road N 26 to Bavigne; ± 6 km SW of Wiltz, north Luxembourg (see Fig. 1).
Elevation : 433 m
Land form : north facing valley side slope (lower slope) of a tributary of the Birbaach river
Slope : 17°
Vegetation : mixed oak-beech forest, poorly developed

Profile description (abbreviated) :

A 1 0—10 cm dark brown (7.5YR 3/2) gravelly loam, many fresh angular shale and sandstone fragments; moderate medium crumb; clear wavy boundary
A 3 10—31 cm brown (7.5YR 4/4) gravelly loam, many fresh angular shale and sandstone fragments; moderate medium and coarse crumb; clear wavy boundary
B 31—45 cm yellowish brown (10YR 5/6) very gravelly and stony loam, very many more or less flat shale and sandstone fragments (up to 25 cm), mostly parallel to the surface; moderate medium subangular blocky; abrupt wavy boundary
II-C + 45 cm olive yellow (2.5Y 6/6) loamy gravel and stones, dominant shale and sandstone fragments

N.B. Roman II numeral is based upon certain micromorphological caracteristics (charcoal fragments, para-aggregates) of the uppermost 45 cm of the profile.

NOTHUM 3 (CONTINUED)

Micromorphological description :

Horizon :	A1	A 3	B
Lithorelicts :	many shale and sandstone fragments (2—10 mm), colours in incident light gray, yellow, orange, red, high and low sphericity, subangular, subrounded and rounded	same as A 1 horizon	same as A 1 horizon
Humiskel :	many very coarse root fragments with birefringence	common medium and coarse root fragments with birefringence	few to common medium and coarse, sometimes very coarse root fragments with birefringence (sometimes very weak)
Biorelicts :	common charcoal fragments (up to 4.2 mm)	same as A 1 horizon	few charcoal fragments (size of medium and very coarse sand)
Voids :	abundant compound packing voids (macro pores), common joint craze planes parallel to the surface from 3 to 6.5 cm depth (meso pores), few channels (very fine macro pores)	abundant compound packing voids (macro pores), few planes (fine and medium meso pores), few channels (fine meso and very fine macro pores), common vughs in aggregates (meso pores)	same as A 3 horizon, maximum porosity from 31 to 36 cm depth
S-matrix :	the fine earth of the horizon mainly consists of fecal pellets	the fine earth of the horizon mainly consists of loose aggregates with a porphyroskelic related distribution pattern	same as A 3 horizon

NOTHUM 3 (CONTINUED)

Skeleton grain :	many silt and few to common very fine sand grains, dominantly quartz, fewer mica's, high sphericity (quartz), low sphericity (mica's),subangular to sub-rounded, occur in aggregates and between fecal pellets	many fine silt (mica's) and silt grains, common very fine sand and few fine sand grains, mainly quartz, high (quartz) and low (mica) sphericity, subangular, occur in aggregates	same as A 3 horizon
Plasma type :	no plasma observed	mullicol in aggregates with brown staining by organic matter	argillicol in aggregates with brown iron staining
Plasma reorientations :	not observed	not observed	not observed (silasepic plasmic fabric)
Cutans :	not observed	not observed	not observed
Glaebules :	not observed	not observed	not observed (silasepic plasmic fabric)
Pedotubules :	not observed	few extremely coarse ortho and meta aggrotubules	same as A 3 horizon
Fecal pellets :	abundant medium dark brown single or weakly welded, sometimes strongly welded organic fecal pellets	many to abundant coarse and very coarse matric fecal pellets, single to strongly welded, very few medium single organic fecal pellets, mostly in clusters	not observed
Aggregates :	not observed	many mullicol aggregates	many argillicol aggregates

4) *Profile number :* Breimicht 2

Classification : thaptohapludalfic udorthent (dystric regosol, overlying truncated orthic luvisol)
Location : on the slope called « Breimicht » 1.35 km WSW of Maison Schuman; ± 6 km SW of Wiltz, north Luxembourg
Elevation : 423 m
Land form : structurally controlled (?) narrow steplike interruption in the steep valley side slope (lower slope) of the Birbaach river
Slope : angle of step 13°, angle of lower slope 26°
Vegetation : mixed oak-beech forest

Profile description (abbreviated) :

A 1 0—9 cm very dark gray brown (10YR 3/2) gravelly loam; weak medium crumb; very friable; abrupt smooth boundary;
C 1 9—35 cm dark brown (10YR 3/4) gravelly loam; many fresh angular shale and sandstone fragments (up to 2 cm); weak medium crumb (inherited); very friable; clear wavy boundary
C 2 35—45 cm dark brown (10YR 3/4) very gravelly and stony loam (up to 10 cm); dominant fresh shale and sandstone fragments; abrupt wavy boundary
II Btb 45—65 cm yellowish brown (10YR 5/4) stony to very stony loam; many to very many fresh shale and sandstone fragments (up to 20 cm); weak fine angular blocky; friable, patchy thin cutans of clay minerals with iron oxides and hydroxides; clear smooth boundary
III R + 65 cm ligth gray to pale yellow (2.5Y 7/2—7/4) fractured bed rock in situ (shale and sandstone)

BREIMICHT 2 (CONTINUED)

Micromorphological description :

Horizon :	A 1	C 1	II Btb
Lithorelicts :	common shale and sandstone fragments (up to 10 mm), boundaries sharp and prominent or faint, high and low sphericity, subangular to rounded, colours in incident light gray, yellow, brown, orange, red	many shale and sandstone fragments (up to 9 mm); rest as A 1 horizon	many shale and sandstone fragments (up to 15 mm), boundaries sharp and distinct (larger ones) or faint (smaller ones)
Humiskel :	common to many brown to dark brown medium and coarse root fragments with birefringence, few to common without birefringence	same as A 1 horizon	very few red brown very coarse root fragments with birefringence
Biorelicts :	very few to few charcoal fragments (sand size)	few charcoal fragments (sand size)	not observed
Voids :	abundant compound packing voids (very fine macro pores), common vughs (fine and medium meso pores), few channels (coarse macro pores)	common joint craze planes, more or less parallel to the surface (micro, meso and fine macro pores), common vughs (medium meso and fine macro pores)	common vughs (coarse meso and fine macro pores), few planes(medium meso pores)
S-matrix :	porphyroskelic related distribution pattern	same as A 1 horizon	same as A 1 horizon
Skeleton grain :	many silt and few very fine and fine sand grains, dominant quartz, fewer mica's	same as A 1 horizon	common silt, few very fine sand and very few fine sand grains, dominantly quartz, few mica's

BREIMICHT 2 (CONTINUED)

Plasma type :	mullicol with a silasepic plasmic fabric, dark and light brown in incident light due to organic matter	same as A 1 horizon, but only light brown in incident light	argillicol, stained brown by iron, silasepic plasmic fabric, very locally sepic
Plasma reorientations :	not observed	not observed	very locally fine to medium masepic plasmic fabric and fine skelsepic
Cutans :	not observed	not observed	few to common ligth brown strong continuous thin and medium vugh, plane and channel illuviation ferri-argillans; few dirty brown weak continuous medium and thick vugh and channel illuviation ferriargillans sometimes completely filling the voids
Glaebules :	few dark brown coarse ferric nodules, sharp and distinct boundaries	common medium and coarse ferric nodules with distinct and sharp or diffuse boundaries	common rounded or irregular dark brown medium and coarse ferric nodules with diffuse boundaries, few medium ferric nodules with sharp boundaries; few light brown strong continuous fine and medium papules
Pedotubules :	not observed	very few very coarse ortho aggrotubules	not observed
Fecal pellets :	many dark brown medium and coarse matric fecal pellets, single and welded; very few light brown medium organic fecal pellets, single to strongly welded, in clusters in root remnants	common to many dark brown medium to very coarse matric fecal pellets, mostly strong-ly welded	very few organic fecal pellets in root remnants

5) *Profile number :* Groendchen 7

Classification : thaptohapludalfic udorthent (dystric regosol, with a buried luvisol in the subsoil)
Location : 250 m north of a point at 1.7 km south west of Maison Schuman along road N 26 from Maison Schuman to Bavigne; ± 6 km south west of Wiltz, north Luxembourg
Elevation : 430 m
Land form : centre of east-west running dry valley, tributary to the Birbaach river valley.
Slope : 5° 30' in direction of valley
Vegetation : one year old spruce plants between stumps of recently cut spruce forest

Profile description (abbreviated) :

0,2 cm very dark brown (7.5YR 3/2) partly decomposed organic matter; abrupt smooth boundary
C 0—40 cm dark brown (7.5YR 4/2) slightly gravelly loam; very weak fine angular blocky (inherited); friable; abrupt wavy boundary
II Bb 40—70 cm yellowish brown (10YR 5/6) very stony loam and dark brown (7.5YR 4/2) loam from overlying horizon in pockets; very many fresh sandstone and shale fragments (up to 15 cm), mostly parallel to the soil surface, angular blocky; friable; abrupt wavy boundary
III Btb 70—135 cm + yellowish brown (10YR 5/6) stony loam; fine angular blocky; firm; patchy thin cutans of clay minerals with iron oxides and hydroxides

In this pit the C or R horizon was not reached at a depth of 135 cm. In a pit a few metres up the side slope of the dry valley, where the solum was thinner (profile Groendchen 9), the III Btb horizon appeared to overly a C horizon composed of weathered, gravel sized shale and sandstone fragments.

GROENDCHEN 7 (CONTINUED)

Micromorphological description :

Horizon :	O	C	II Bb	III Btb
Lithorelicts :	not observed	2—33 cm : common, and 33—40 cm : many sandstone and shale fragments (up to 1.3 cm); low and high sphericity; angular to subrounded and rounded (smaller ones); yellow, orange, red and brown in incident light	many shale and sandstone fragments (up to 1 cm); rest as C horizon	common shale and sandstone fragments (up to 1 cm); shale fragments rounded and difficult to to recognise; rest as C-horizon
Humiskel :	abundant medium to very coarse redbrown root and leaf fragments with birefringence, occurring in bands parallel to the surface	few to common medium to extremely coarse brown, blackbrown and redbrown root remnants with and without birefringence	few very to extremely coarse blackbrown root remnants without birefringence	few medium to extremely coarse blackbrown and redbrown root remnants with and without birefringence
Biorelicts :	not observed	few charcoal fragments fine to very coarse sand size	not observed	very few charcoal fragments, medium sand size

GROENDCHEN 7 (CONTINUED)

Voids :	not determined	common to abundant vughs (meso and very fine macro pores), abundant compound packing voids between fecal pellets (fine meso pores); common to many craze planes (micro to very fine macro pores); few channels (coarse meso and very fine macro pores)	common vughs (fine meso to very fine macro pores) common craze planes (micro to very fine macro pores); few channels medium and coarse)	common to many vughs (fine meso to medium macro pores); few to common channels (coarse meso and very fine macro pores); few to common planes (micro to very fine macro pores)
S-matrix :	not relevant	porphyroskelic related distribution pattern	same as C horizon	same as C horizon
Skeleton grain :	not observed	abundant silt, common very fine and fine sand grains; dominantly quartz, fewer mica's; high (quartz) and low (mica) sphericity; subangular to subrounded	same as C horizon	same as C horizon
Plasma type :	not observed	mullicol with a silasepic plasmic fabric; dark brown in incident light due to organic matter	little argillicol with a silasepic plasmic fabric	same as II Bb horizon

GROENDCHEN 7 (CONTINUED)

Plasma reorientations :	not observed	not observed	not observed	silasepic, only very locally insepic plasmic fabric
Cutans :	not observed	not observed	very few thin brown continuous illuviation ferriargillans	few to common, thin to very thick, yellow and brown (sometimes dirty), (strong) continuous illuviation ferri-argillans; few medium to thick compound illuviation ferriargillans (strong continuous yellow ferriargillans below a dirty weak continuous illuvia-tion ferriargillan)
Glaebules :	not observed	few to many, dark brown and blackbrown, fine to coarse ferric nodules without skeleton grains, with sharp and diffuse boundaries	many sharply bounded medium and coarse ferric nodules; very few, brown, thin, strong continuous argilla-ceous papules (some of them in the pockets of a lithorelict)	few to common ferric nodules (irregular and subrounded, with sharp and diffuse boundaries medium and coarse, with and without skeleton grains); few to common yellow or brown strong continuous medium argilaceous papules

GROENDCHEN 7 (CONTINUED)

Pedotubules :	not observed	few to common, very to extremely coarse, ortho-aggrotubules with faint and sharp boundaries	not observed	not observed
Fecal pellets :	many fine dark brown single and welded organic fecal pellets; few brown single medium organic fecal pellets	many to abundant matric fecal pellets (brown and darkbrown single and welded, medium, few very coarse); common to many, medium dark brown organic fecal pellets; random and in clusters. N.B. The bulk of the soil material consists of matric fecal pellets	very few to few single and welded, fine and very coarse matric fecal pellets	not observed
Aggregates :	not observed	very few light-brown para-aggregates, ironstained	not observed	not observed

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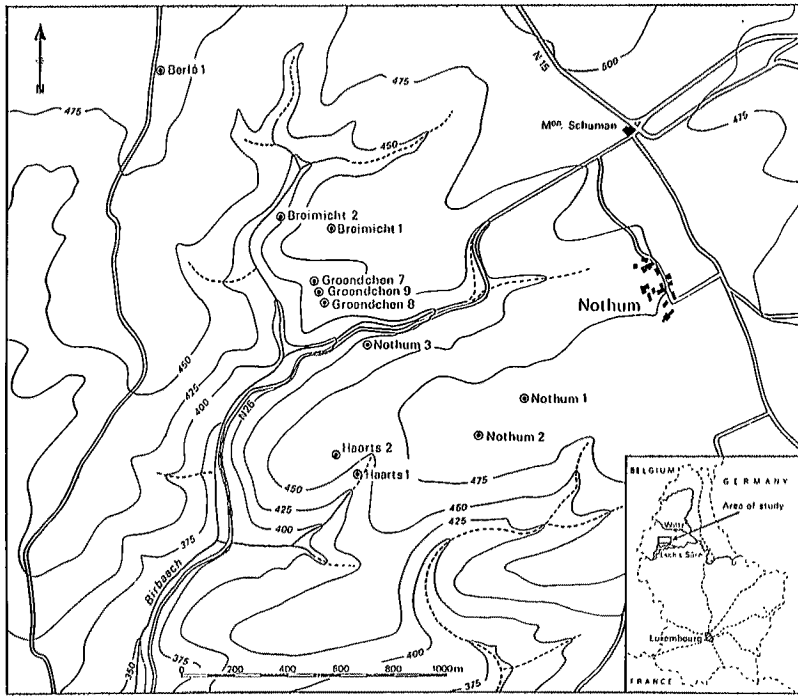


Fig. 1 : Topography of the area of study and location of profiles.

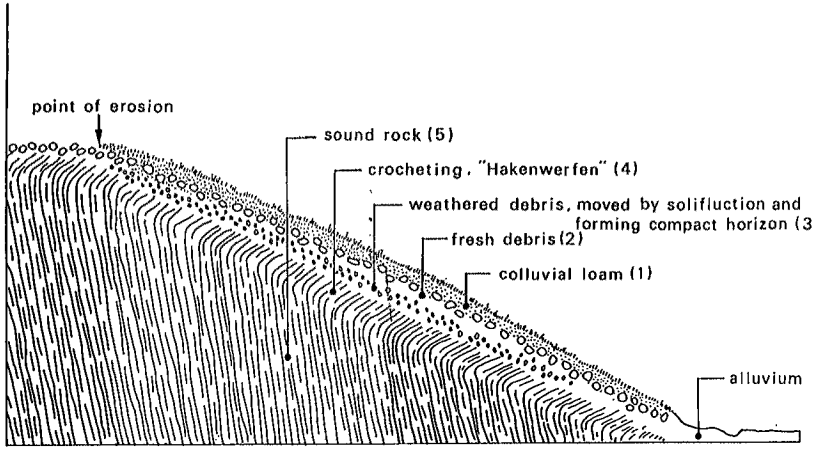


Fig. 2 : Idealized slope section according to Hermans (1955).

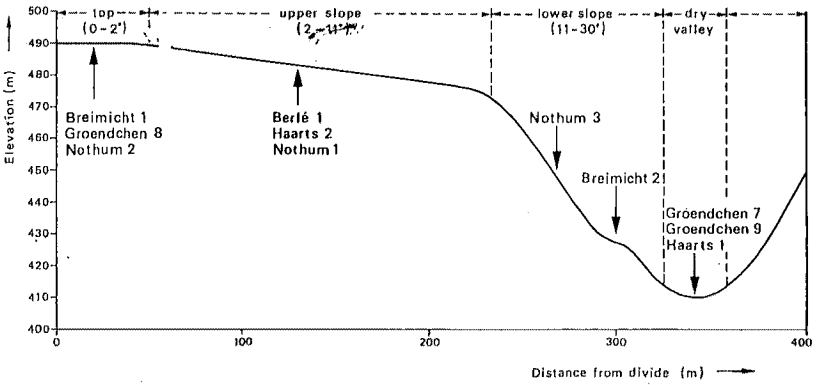


Fig. 3 : Schematic representation of landscape units with location of profiles.

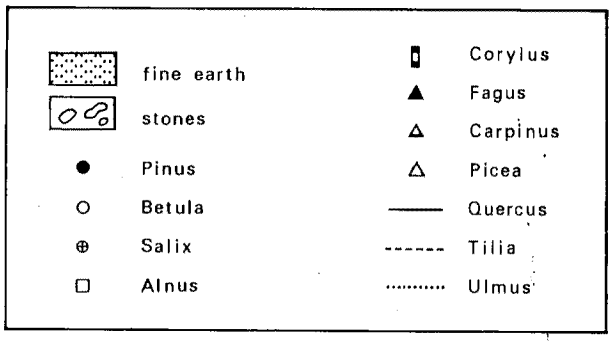


Fig. 4 : Key to pollendiagrams.

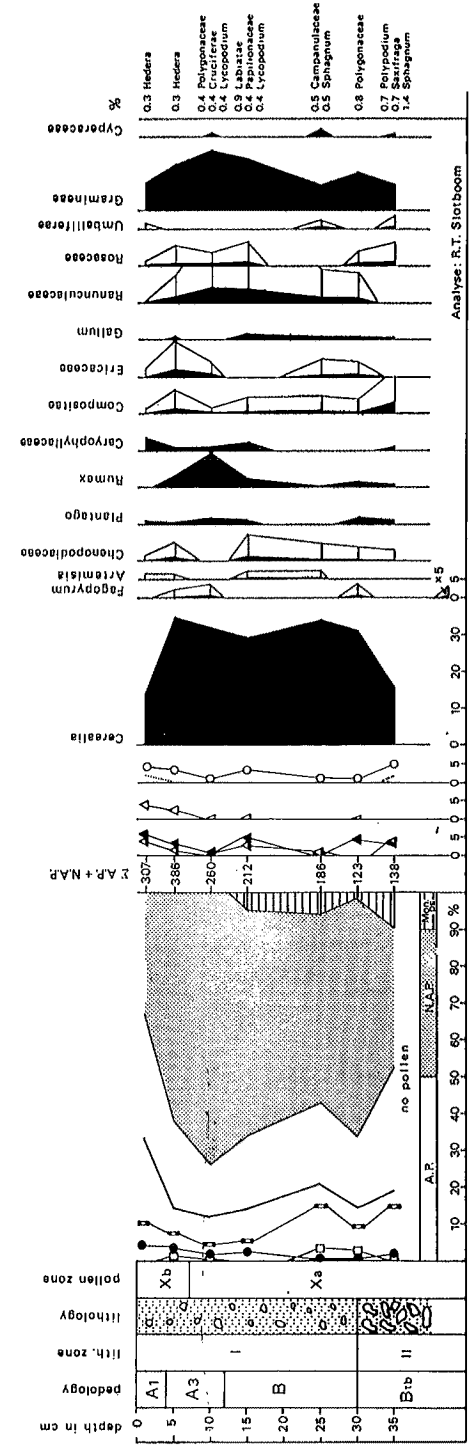


Fig. 5 : Pollendiagram of profile Haarts 2 (upper slope).

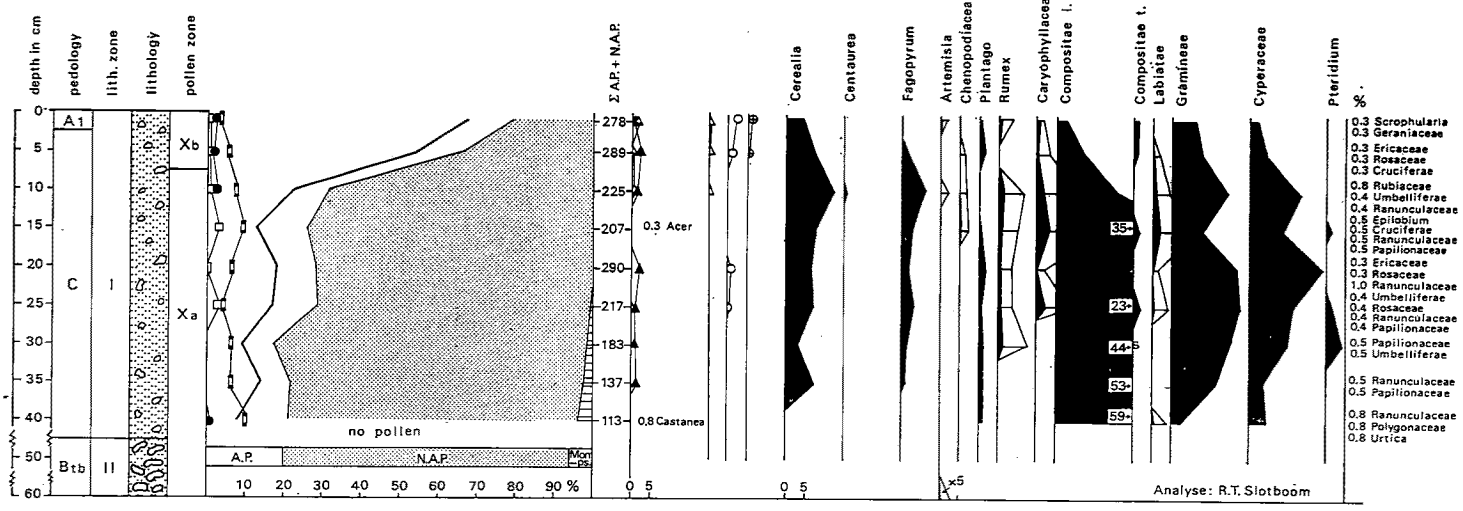


Fig. 6 : Pollendiagram of profile Haarts 1 (dry valley).

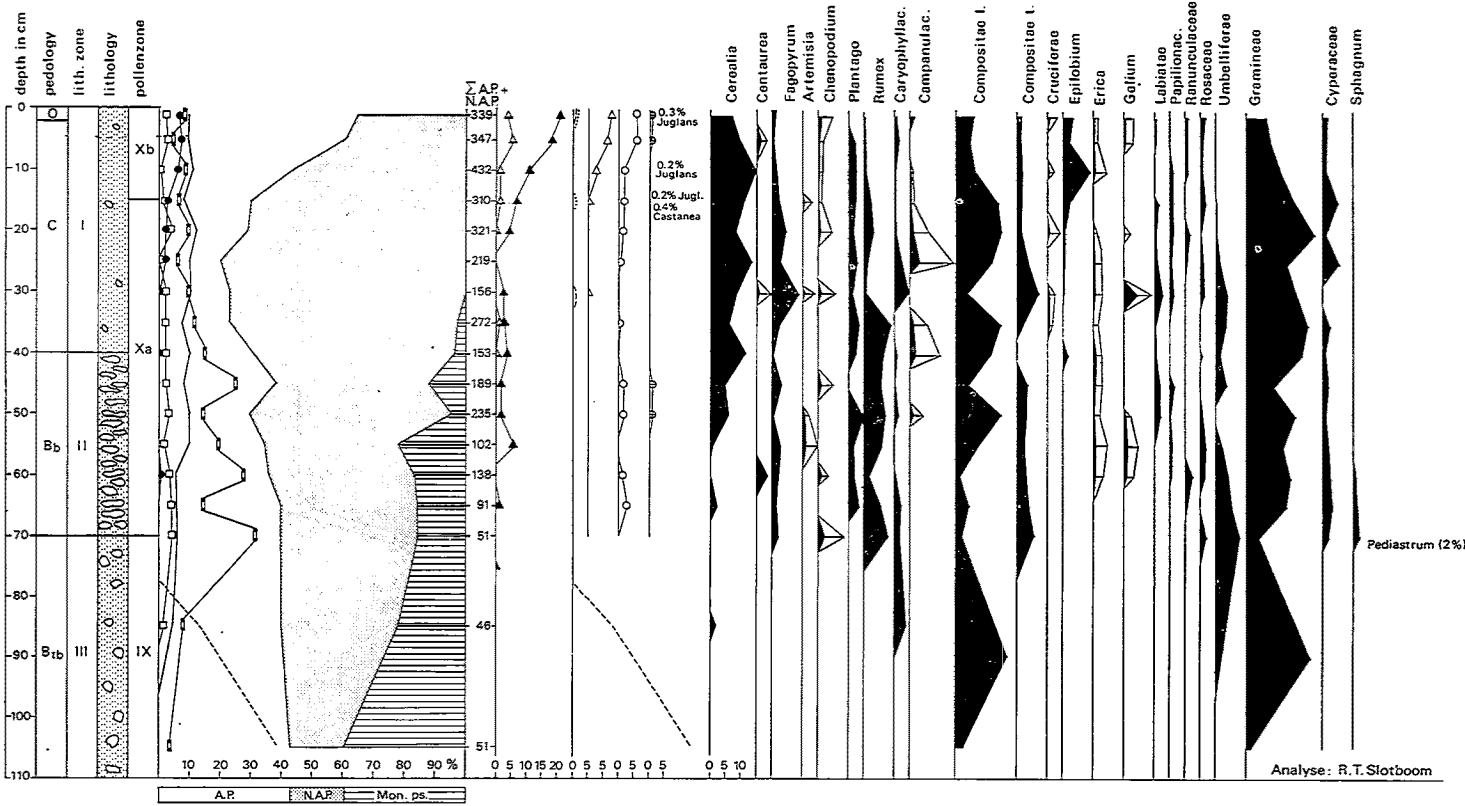


Fig. 7 : Pollendiagram of profile Groendchen 7 (dry valley).