EVIDENCE FOR HOLOCENE REGOLITH INSTABILITY ON A SLOPE NEAR TROINE (Oesling, Luxembourg)

Peter A. RIEZEBOS & Rudolf T. SLOTBOOM

ABSTRACT

In a foundation excavation near Troine (Oesling, Luxembourg) the bedrock-covering mantle of slope material appears to consist of a gravelly loam overlying a congelifractate deposit. Within the loam a discontinuity is locally discernable. A study of particle-size distribution, heavy minerals, pollen and individual crumbs in thin sections indicates that this discontinuity represents an unconformity. The results show that above the unconformity a loamy slope deposit of Subatlantic age occurs while beneath it an erosion remnant of loam accumulated before the end of the Allerød is found. The data provide no unambiguous evidence for phases of instability in the period of time between the Allerød and the Subatlantic.

RESUME

Dans l'excavation d'un chantier de construction près de Troine (Oesling, Luxembourg) les dépôts de pente qui couvrent la roche solide semblent consister en un dépôt fracturé par le gel, ce dernier étant par du limon à cailloutis. Au sein du limon on observe localement une discontinuité. L'étude de la granulométrie, des minéraux lourds, des pollens indique que cette discontinuité est à considérer comme une vraie discordance. Les résultats montrent au-dessus de la discordance un dépôt de pente limoneux d'âge subatlantique, au-dessous un reste partiellement érodé de limon déposé avant la fin de l'Allerød. Les données fournies ne permettent pas d'admettre comme certaines des phases d'instabilité dans la période entre l'Allerød et le Subatlantique.

INTRODUCTION

In a paper discussing the benefit oh the palynological study of slope deposits (RIEZEBOS & SLOTBOOM, 1974), evidence was adduced that the slope-covering materials in the Oesling had been subjected to displacement during the Subatlantic substage. However the sections studied in these unconsolidated materials were limited in number, confined to a comparatively small area of the Oesling and were rather shallow, not exceeding 70 cm. Moreover, the sites investigated were mainly beneath woodland.

A construction pit near Troine in the northern part of the Oesling (Fig. 1) furnished the opportunity to sample and study

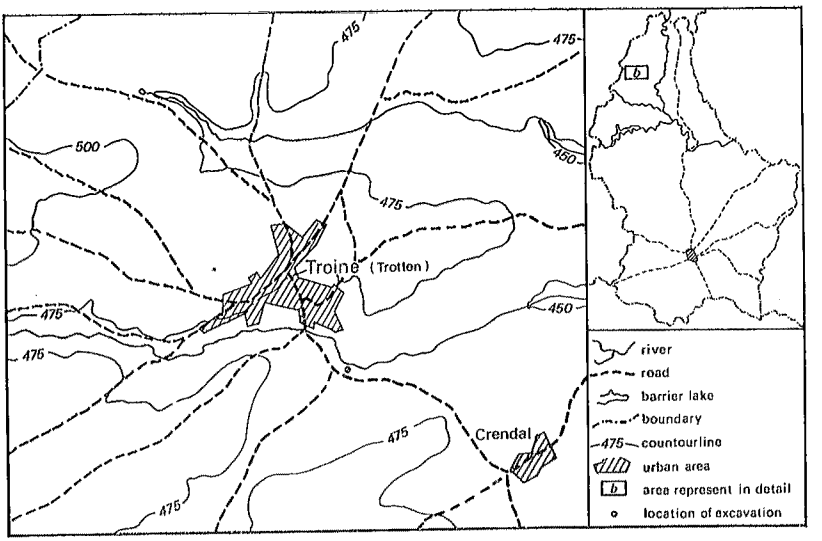


Fig. 1 Location of the foundation excavation

regolith materials at a locality not only at a fair distance from the previously investigated sites, but also in an area with sparse forests and used presently mainly for agriculture. Besides, a considerable thickness of the unconsolidated slope material was exposed in the section. The foundation excavation, which uncovered the exposure, was found at an altitude of 460 meter on a lower N. E. facing slope and passed imperceptibly into the alluvial plain of a small river. The distance to this rivulet, the Troine, was about 50 meters.

This paper reports some data gained from the exposed rock-covering materials and the deduced chronological implications of their genesis.

GEOLOGIC SETTING

The area around the village of Troine forms part of the south-eastern limb of the anticline of Bastogne and is underlain by metamorphic rocks of Lower Devonian age. This epoch comprises in the Oesling two formations, i. e. the Siegenian and the Emsian. The geological map shows that here the Upper Siegenian (Sg 3), being principally composed of coarse slates with a commonly poorly develcped fissility, occurs below the mantle of surface materials.

The dissected plateau of the Oesling at an altitude of about 500 m, is generally assumed to be a peneplain. There is a diversity of opinion as to its age. LUCIUS (1957) is among those investigators considering it as a fossil, pre-Triassic peneplain, reexcavated by erosion in the Cenezoic, while PIKET (1960) and VERHOEF (1966) hold the view that its origin dates from the Tertiary. A considerable part of the present Oesling surface is occupied by valley slopes, most of which have probably been formed by Pleistocene incision.

Concerning the loose mantle above the solid bedrock, several statements have been made in the past. Generally they were considered to be related to the supposed age and type of the overlain relief forms. Accordingly these unconsolidated materials were looked upon as in situ weathered products of Tertiary age, Pleistocene solifluction deposits and products of Postglacial creep.

PROFILE DESCRIPTION

In Figure 2 an outline of the construction pit is given, which indicates the positions of the sections represented in Figure 3. The excavation was accessible north of the line BC in Figure 2 as the rest was filled up with water. The depth of the northern part varied between 0 and about 2 m under the ground surface (A B C D Fig. 2). South of BC in Figure 2, however, the excavation was more than 5 m deep. As is evident from Figure 3a three zones can be distinguished in the exposure.

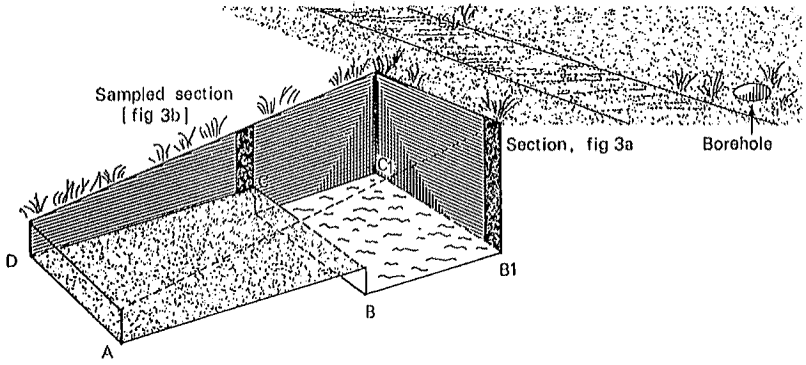


Fig. 2 Outline of the excavation with the position of the sections shown in Figure 3.

Zone I

This zone comprises the bedrock as far as visible in the exposure. Its very disturbed upper part still shows, as Figure 3a



Fig. 3 a Part of the south face of the excavation showing the three zones distinguished.

indicates, slaty cleavage, Locally slight outcrop curvature seems to occur demonstrating that relative movements have occurred in the regolith. The distance between the ground surface ant the upper boundery of the bedrock is rather variable. At the east face (DC' Fig. 2), this irregular boundary inclines downslope more steeply than the land surface, while at the west face (AB', Fig. 2) it is more or less parallel to it. Due to a complete absence of the original structure in the overlying zone of rock debris the transition to zone II may be locally rather sharp.

Zone II

This zone is largely composed of slate fragments of cobble size and larger. Their decreasing dimensions towards the upper surface of the zone is also illustrated in Figure 3a. The angularity of the cobbles and boulders, especially in the lower part seems rather high, suggesting an origin by frost shattering after removal of possible overlying fine-textured weathering and soil material. A rather indistinct stratification suggests that these congelifracts have very probably been carried downslope coming to rest approximately parallel to the slope. This stratification becomes more outspoken in the upper part of the congelifractate deposit, which has a rather varying thickness. Because of the diminishing size of the slate fragments and the increase of fine matrix material in the upper part, the contact with the uppermost zone is diffuse. Water seen flowing from this zone and the upper part of zone I indicated that they might often be important water-transporting layers.

Zone III

The material in this zone consists of grey-brown loam containing gravel-sized rock fragments. The gravel fraction is mainly composed of slate fragments, some of which are rather coarse textured. Occasionally vein quartz has been observed. The fragments are generally angular, though the coarser-textured specimens show a slight degree of rounding. No bedding features could be detected. In depth, this zone varies from about 1.50 m in the south face to 2.10 m in the east face. Here at a depth of 1.70 m below the surface a discontinuity was found which was lacking in the west face. Below this level the

loamy material displays a different colour chiefly owing to the appearance of yellow hues and the occurrence of reddish-coloured mottles. The loam is more closely packed and the number of included rock fragments seems to be smaller. Particularly the difference in consistency above and below this level is conspicuous (Fig. 3b). All these features suggested that

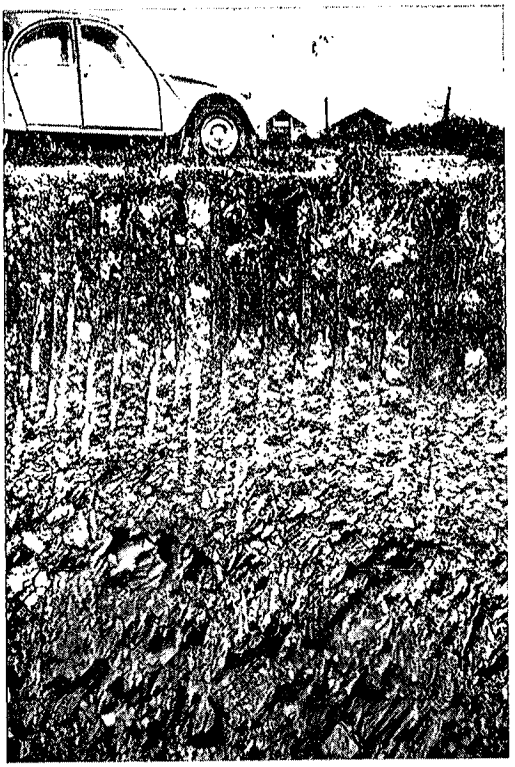


Fig. 3 b Part of the east face illustrating the difference in consistency of the loam above and below the discontinuity.

the discontinuity might represent an unconformity corresponding to a perriod of erosion and/or non-deposition. In the following, therefore, the upper and lower parts of this zone will be designated respectively as IIIa and IIIb.

SAMPLING AND ANALYTICAL PROCEDURE

Material from a section in the east face of the pit was collected for particle-size, heavy-mineral, thin-section and

palynological analysis. Being highly disturbed by the digging, the upper 60 cm of the exposure was excluded from the sampling. Instead, samples were collected from a bore hole upslope a few meters south of the excavation (see Fig. 2). At this site the thickness of the covering loam does not exceed 90 centimeters. Materials from zone I and II have been excluded from sampling, since it would be technically impossible to study their main components according to the methods mentioned above. However, some loam was scratched from the cobbles at the top of zone II to investigate its pollen content.

It is true that the loam found on and between the cobbles would be suitable material for pollen anlysis, but its cogenetic nature must be strongly doubted in view of the subsurface water flow observed in the field. The fact that the materials from zone I and II have not been included in this investigation, does not mean that these zones are considered to be insignificant for the present kind of study. On the contrary they play a role in the interpretation of the data obstained and, as will be discussed in a forthcoming paper, zone II is very probably of importance for the present-day slope and drainage pattern development in the Oesling.

After the usual pretreatment particle-size analysis was carried out on the samples by applying the dry sieving method on the 2000—50 μm and the pipette analysis on the <50 μm sized material. The content and distribution of the included gravel-sized fragments was additionally established. The material for pollen analysis was treated according to the Iversen-method combined with a gravity separation in order to eliminate possible mineral particles. Heavy minerals were determined and counted in concentrates separated from the 210—105 and 105—50 μm fractions. Thin sections were prepared of aggregates from some samples using Synolite polyester resin.

RESULTS

a) Mechanical distribution (see Table 1).

The major feature shown by the gravel fractions (Table 1 A) is a gradual increase of weight percentages upwards in the section. Only the medium-gravel content of sample 3 is not in agreement with this picture. The particle size

Table 1 A

sample no	Depth	medium gravel 8—16 mm fine gravel	4—8 mm	very fine gravel 2—4 mm	sand, silt an clay <2 mm	sand 2000—50 µm	silt 50—2 µm	clay <2 µm
5	60— 70 cm	3.2	7.9	6.5	82.4	18.5	64.5	17.0
4	90—100 cm	3.1	5.8	6.0	85.1	16.0	66.5	17.5
3	120—130 cm	5.8	5.6	5.9	82.7	12.5	69.5	18.0
2	140—170 cm	2.8	3.9	3.2	90.1	11.0	72.0	17.0
1	170—210 cm	1.0	1.0	2.3	95.7	13.5	63.5	23.0
				B				
C4	20— 30 cm	n.d.	n.d.	n.d.	n.d.	16.5	67.0	16.5
C4	20— 30 cm	n.d.	n.d.	n.d.	n.d.	13.5	67.5	19.0
C2	60— 70 cm	n.d.	n.d.	n.d.	n.d.	16.0	63.0	21.0
C1	80— 90 cm	n.d.	n.d.	n.d.	n.d.	15.5	62.0	22.5

Table 1 A Gravel contents and mechanical composition of the <2 mm fractions of the samples collected in the Troine excavation.

B Mechanical composition of the <2 mm fractions of the samples from a bore hole just south of the excavation.

distributions of the <2 mm fractions are very similar to each other. The minor difference is that sample 1 contains about 5 percent more clay than the remaining samples which display, going upwards in the section, a slight increase in sand percentages with a corresponding decrease in the silt content. The gravel contents in the sample C 1—4 have not been determined (Table 1 B) as these materials have been obtained by a soil auger and the results would be rather unreliable. The size distributions of the <2 mm fraction in the samples show clay contents gradually increasing with depth.

b) Heavy minerals (see Fig. 4).

Two groups of heavy minerals are distinguished. The first one comprises the volcanic minerals which are generally assumed to have been supplied by Eifel eruptions. The second group contains the remaining heavy minerals derived principally from the parent rock. Opaque and composite

Fig. 4

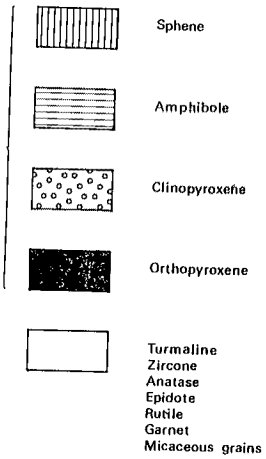
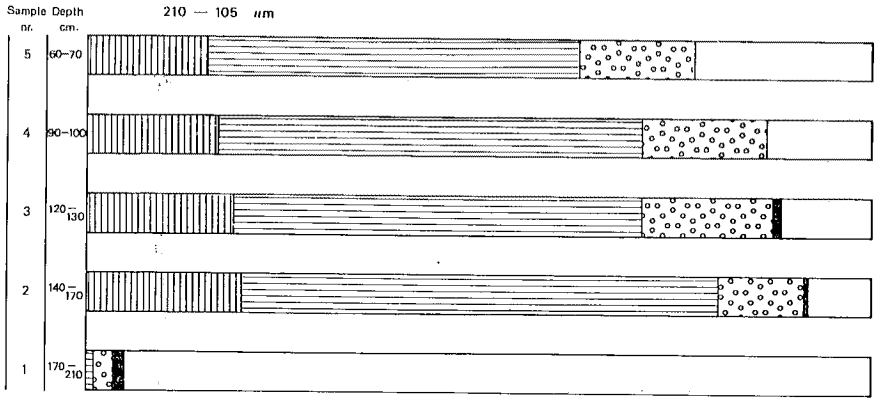

Group 1
Sphene
Amphibole
Clinopyroxene
Orthopyroxene
Group 1
Turmaline
Zircone
Anatase
Epidote
Rutile
Garnet
Micaceous grains

Fig. 4 a


Sample nr.
Depth cm.
210 — 105 µm
5
60–70
4
90–100
3
120–130
2
140–170
1
170–210

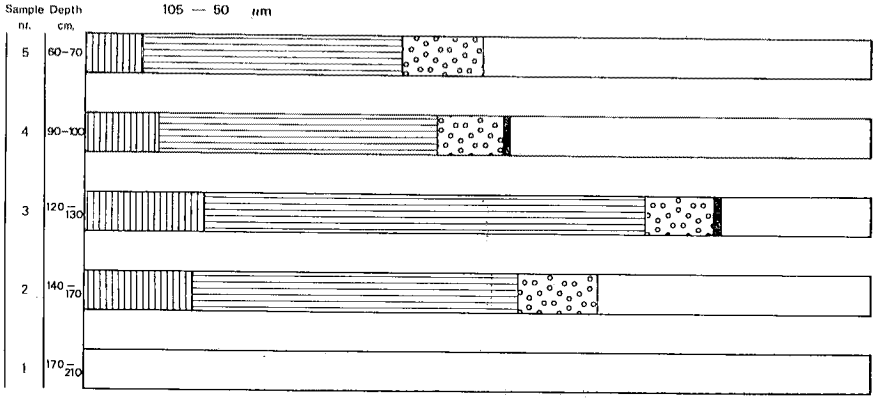

Sample nr.
Depth cm.
105 — 50 µm
5
60–70
4
90–100
3
120–130
2
140–170
1
170–210

Fig. 4 b

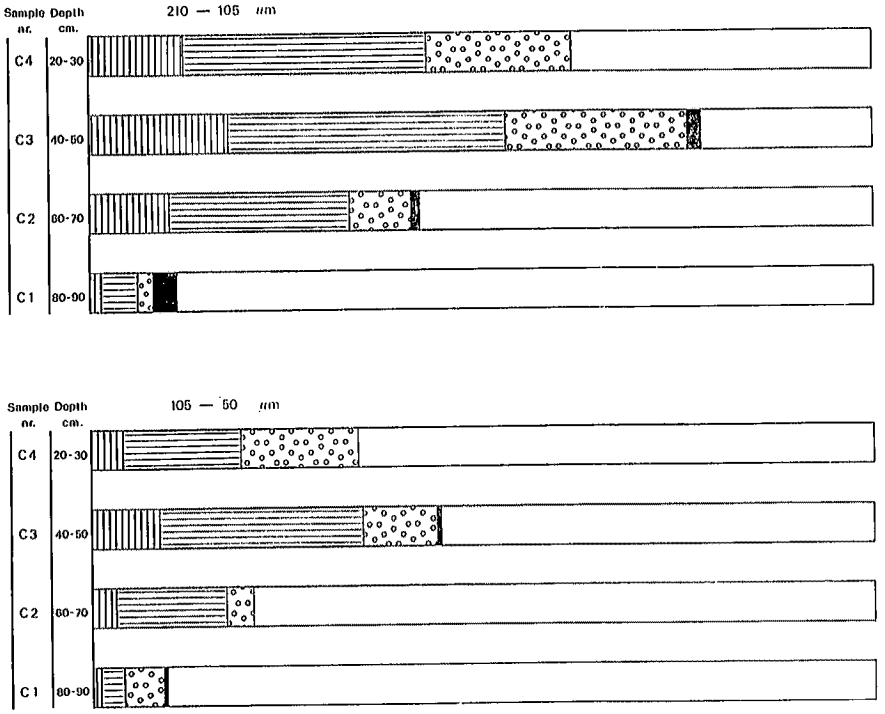


Fig. 4 Heavy-mineral compositions of the samples from the excavation (a) ant the bore hole (b).

grains have not been recorded. Within the first group the commonly occurring species, amphibole, clinopyroxene, sphene and the occasional orthopyroxene, are distinguished. The outcomes testify that a conspicuous difference exists between the materials from zone IIIa and IIIb for both size grades investigated. In the bore-hole samples (C 1—C 4) the contents of the group 2 minerals are generally higher. The number of mineral particles of group 1 in the lowermost sample (C 4) do display a considerable decrease in content, but sphene which has not been observed in sample 1 (zone IIIb) is still found in both size grades.

c) Internal features of aggregates.

The air-dried sample materials appeared to contain several individual crumbs. Because those from the sample 1 material (zone III b) as apposed to those from the remaining samples

(zone III a) were characterized by an orange to reddish hue, some aggregates from samples 1 and 2 were selected for thin-section preparation. Their microscopic analysis revealed very different characteristics. The aggregates from sample 1 show very distinct cutans which are generally thought to be typical for a Bt soil-horizon (Fig. 5 a. b. c.). Cutans are concentrations of clay and/or organic matter and/or iron components coating pore and channel walls. In the present materials they represent probably ferriargillans, i. e. a type of cutan consisting mainly of clay and iron. In view of their rather ubiquitous presence, a strong supply and subsequent deposition of clay must have taken place after the formation or accumulation of the material of zone III b. This deposition occurred obviously in gravel-containing slope material as the cutans also have been found partly coating the surface of included rock fragments. The aggregates from the sample 2 material, however, failed to exhibit this feature. Instead papules, which are remnants of cutans, were occasionally found. Moreover a much higher porosity was observed in the thin section of this sample (Fig. 5d).

d. Palynological findings.

The diagram (Fig. 6) shows that the number of included pollen, being already low in the material from zone IIIa, drops to nil in the uppermost spectra of zone III b. In the remaining spectra of this zone the number of pollen does not exceed 50. It is conspicuous that, thought the spectra display a poorness of arboreal pollen, in one spectrum at a depth of 192 cm a comparatively large amount was found. Also remarkable is the abundance of charcoal particles in the spectra of zone IIIa.

The aboreal species observed are *Pinus, Betula, Carpinus, Fagus, Quercus, Corylus, Alnus* (IX). Between 110 and 90 cm below the surface an expansion of arable farming is suggested by Cerealia and *Fagopyrum*. Comparaison with the Hosingen diagram (RIEZEBOS & SLOTBOOM, 1978), suggests that the simultaneous appearance of *Centaurea* and *Fagopyrum* with the Cerealia maximum at a depth of circa 110 cm very probably corresponds with the first extension of *Fagopyrum* in the Hosingen diagram

Fig. 5a

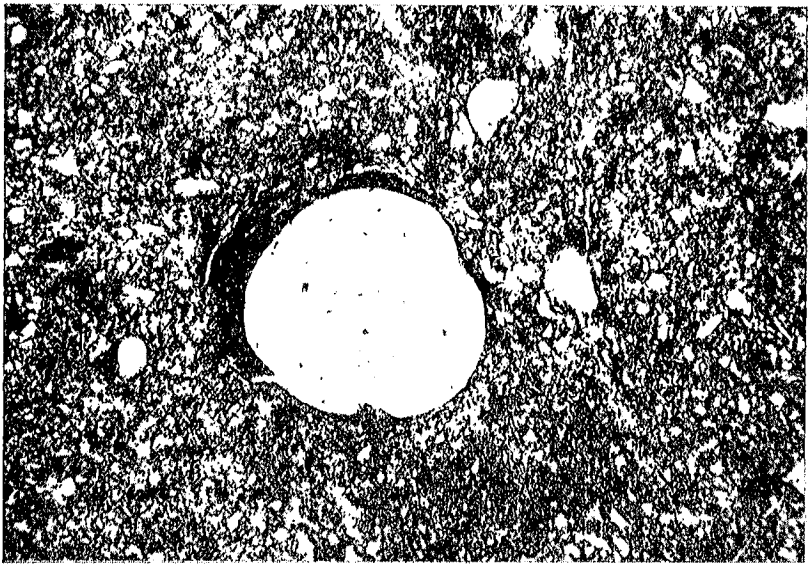


Fig. 5 a, b and c show examples of cutans found in the material of subzone IIIb. d illustrates the absence of this feature and the greater porosity of the III a material

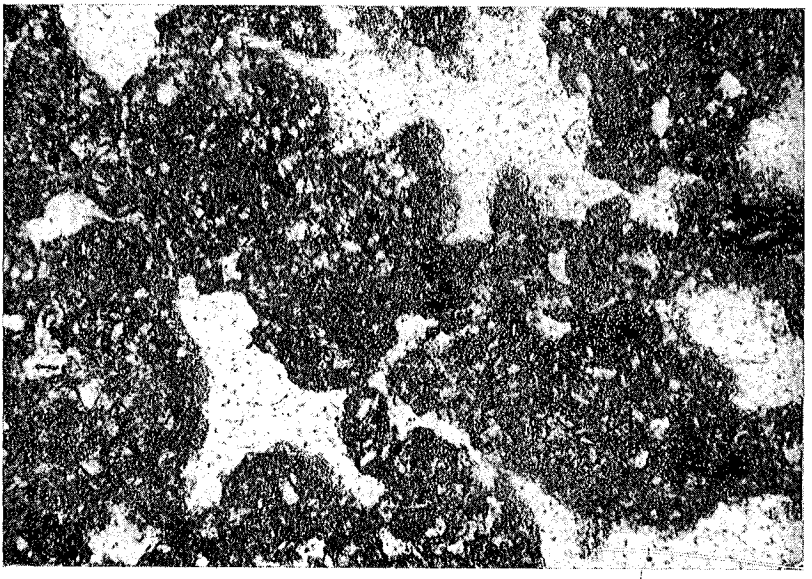
Fig. 5b



Fig. 5c



Fig. 5d



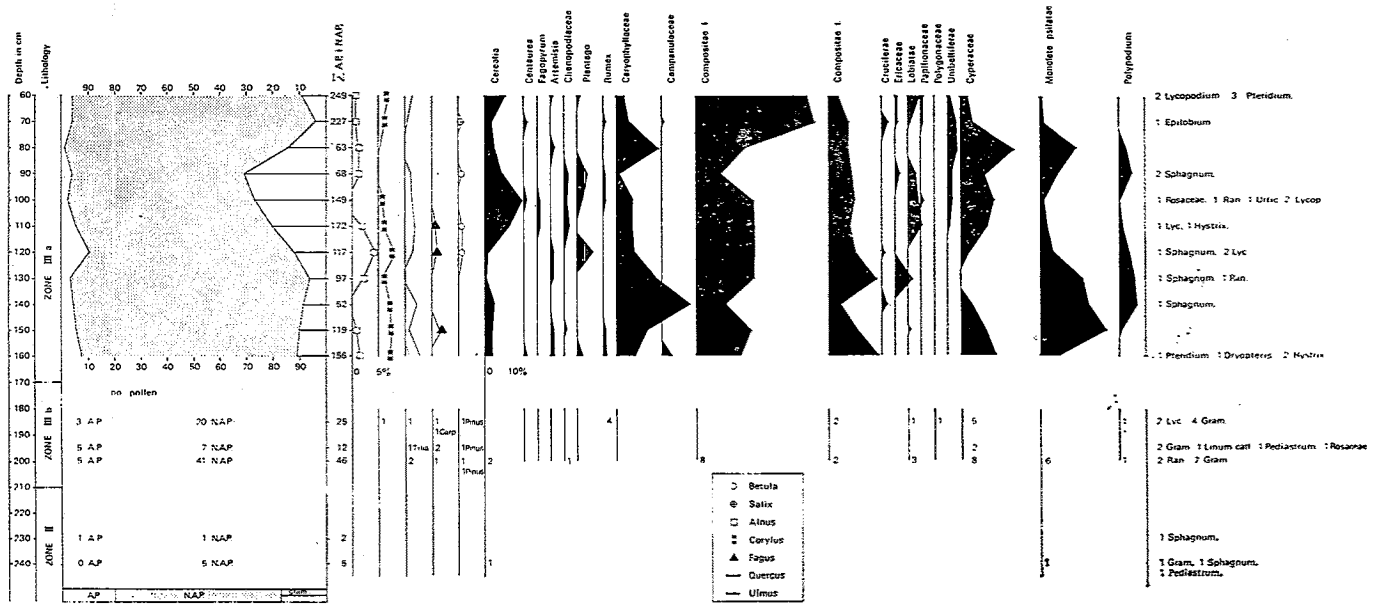


Fig. 6 Pollendiagram of zone III.

which has been dated as about 1500 A.D. and not with the second *Fagopyrum* extension (± 1750 A. D.) because higher up in the present section neither *Picea* nor a higher content of *Pinus* has been found. The recognition of a pollen stratification in subzone III b is prevented by the scarcity of pollen and spectra. From the presence of *Fagus, Carpinus* and Cerealia the material might be inferred to be of subatlantic age. The data obtained from the bore-hole samples (Table 2) show that already from a depth of 25 cm downward a considerable decrease in the pollen content occurs.

DISCUSSION

Loose rock debris on slopes is a puzzling material, not in the least because it reprsents the very beginning of a sedimentary cycle. It is a substance that has been mobilized, but scarcely subjected to processes of differentiation during transfer. Hence a poorly developed or a lack of sorting is generally characteristic. If, such as in the present case, a concentration of particles in one or more size grades is found, it is often an inherited feature showing a close relationship with the parent rock.

Nevertheless, the particle-size distributions found still allow, though in a lesser degree than the other sort of data, zones IIIa and zone IIIb to be discriminated. The somewhat higher clay content — probably due to clay concentration in the cutans — and the lower gravel content established in the zone III b material are the major features supporting this discrimination.

The occurrence of two subzones within zone III is confirmed by several students of heavy-mineral fractions. An eruption of canic activities were recognized in the areas west of the Eifel by several stdents of heavy-mineral fractions. An eruption of late Allerød age in the Eifel region supplied pyroclastic material with a heavy-mineral composition characterized by brown amphibole (40—45%), clinopyroxene (40—50%) and sphene (10—15%) (HULSHOF & al. 1968, JUNGERIUS & al. 1968). Recently another volcanic association consisting of basaltic hornblende (>50%), sphene (circa 25%) and clinophyroxene (<10%) has been found and dated between 26 000 B. P. and 11 000 B. P. BASTIAN & al. 1974, PISSART & al. 1975), but in a more recent study (JUVIGNÉ 1976) this assemblage is also ascribed for the

Table 2

Sample	Depth	Pollen content of the bore-hole samples			
I	15 cm	AP = 9	NAP = 240	8 *Umbelliferae*	1 *Rosaceae*
		2 *Pinus*	102 *Compositae l.*	3 *Ranunculaceae*	1 *Campantlaceae*
		3 *Quercus*	12 *Compositae t.*	1 *Papilionaceae*	1 *Rumex*
		1 *Picea*	49 *Gramineae*	2 *Plantago*	1 *Chenopodiaceae*
		2 *Corylus*	18 Cerealia	2 *Cruciferae*	1 *Geraniaceae*
		1 *Fagus*	16 *Cyperaceae*	2 *Centaurea*	1 *Artemisia*
			11 *Labiatae*	1 *Erica*	1 *Lycopodium*
			5 *Caryophyllaceae*		1 *Mon. psilatae*
II	25 cm	AP = 5	NAP = 45	1 *Caryophyllaceae*	
		1 *Betula*	19 *Compositae l*	3 *Umbelliferae*	
		2 *Corylus*	4 *Compositae t.*	2 *Cruciferae*	
		2 *Quercus*	10 *Gramineae*	1 *Papilionaceae*	
			1 *Cyperaceae*	1 *Cyperaceae*	
			3 *Rosaceae*	1 *Pediastrum*	
			3 *Erica*		
III	35 cm	AP = 2	NAP = 8		
		2 *Corylus*	4 *Compositae l.*		
			2 *Compositae t.*		
			1 *Chenopodiaceae*		
			1 *Artemisia*		
IV	45 cm	AP = 3	NAP = 19	1 *Papilionaceae*	
		1	15 *Compositae l.*	1 *Galium*	
		1	6 *Compositae t.*	1 Cerealia	
		1	17 *Graminae*	1 *Mon. psilatae*	
			2 *Cyperaceae*	1 *Sphagnum*	
			1 *Rosaceae*		
V	55 cm	AP = 1	NAP = 7	1 *Umbelliferae*	
		1 *Tilia*	1 *Compositae l.*	1 *Rubiaceae*	
			1 *Compositae t.*	1 *Mon. psilatae*	
			1 *Gramineae*		
			1 *Cyperaceae*		
VI	65 cm	AP = 1	NAP = 1		
		1 *Quercus*	1 *Gramineae*		

time being to an Eifel eruption during the Allerød. Finally a still older one characterized by augite (circa 50%), basaltic hornblende (circa 25%) and enstatite (circa 25%) has been reported (JUVIGNÉ 1973, 1974, PISSARD & al. 1975). The eruption, producing materials with this association, probably took place during Vistule I from 70 000—62 000 B. P. (Juvigné 1976).

The abundant presence of sphene, brown amphibole and clinopyroxene in the slope material above the discontinuity and the lack of sphene with a proportionally large amount of orthopyroxene in the loam below it, suggest that the III b material came into existence or was accumulated between 62 000 B. P. and 11 000 B.P. The accumulation of the III a material consequently occurred after 11 000 B. P. The presence of some orthopyroxene grains in the lower part of zone III a very probably has been caused by mixing with material from III b on the upward slope. The abundant cutans in the aggregates of sample 1 (subzone III b) combined with the observed papules in sample 2 (lowermost part subzone III a) corroborate this view. The pollen and mineral data obtained from the bore-hole samples south of the excavation (Table 2, Figure 4b) strongly suggest that at this site subzone III b is not present anymore as an individual zone and bas been compltely incorporated in the deposits of zone III a.

When heavy-mineral, palynological and micro-pedological data are considered together, part of the evidence seems contradictory with regard to the sequence of events giving rise to these subzones. Subzone III a represents obviously a slope deposit accumulated between about 800 and 1700 A. D. Pollen and mineral data both support this inference. A pre-Allerød age of subzone III b seems in conflict with the occurrence of pollen (*Carpinus* and Cerealia) in this subzone and the upperpart of zone II, pointing to a subatlantic age of the producing vegetation (see Fig. 6). In the opinion of the present authors, however, these scarce pollen grains can hardly be used as a argument in favour of a Holocene deposition of the material.

As already mentioned, field evidence showed that the disturbed upper part of the bedrock (zone I) and the periglacial shatter zone (zone II) play an important role in the flow of water downslope through the regolithic cover (troughflow). Especially when the congelifractate deposit (zone II) is very

near the surface or only covered by shallow permeable soil material with a limited storage capacity so that the entrance of percolating water is rather rapid, this throughflow may give rise to lateral sub-surface displacements of fine materials originating from the surface and overlying material. Such a sub-surface erosion (chemical and mechanical lateral eluvation) has earlier already been recognized as a denudatial process (RUXTON 1958). It is quite conceivable thate this way « younger » pollen grains have been trapped and still are being trapped in the frost shatterzone and in remnants of former regolithic covers as exemplified here by subzone III b. In any case the material of subzone III b, whether it originated at this site by weathering or arrived by accumulation, does not seem to contain or does not seem to contain anymore original pollen. Therefore, the authors are inclined to believe that the presence of these scarce pollen grains is due to « contamination ».

In this connection also the value of the cutans in subzone III b as indicators for one or more periods of soil formation might be questioned. If percolated water is temporarily stored in the frost shatter zone e. g. after periods of heavy precipitation, the shatter zone overlying loam or its basal part undoubtedly has also been periodically saturated. If moreover conditions at the surface or within the congelifractate deposit were such that the clay was easily dispersed, it is conceivable that the cutans are not necessarily the result of vertical clay transport and subsequent deposition only. They may partly or even exclusively be due to laterally and/or from below upwards the overlying gravelly loam intruding water that conveyed dispersed clay.

The discontinuity at a depth of 1.70 corresponds in any case to an unconformity i. e. a phase of slope instability with erosion and subsequent accumulation and the starting point of the latter can palynologically be rather well established at this site. As this disquilibrium phase has been induced anthropogenically, its commencement will probably vary from place to place in the Oesling. Whether this discountinuity, in view of the abundant cutans found in subzone III b, may also be related to a preceding phase of soil formation and thus a phase of greater slope stability as suggested (RIEZEBOS & SLOTBOOM, 1974, KWAAD & MUCHER, 1977), remains to be seen.

No inference can be made about the original thickness of subzone III b. Only if cutans unambiguously point to soil formation, it may be concluded that this soil originated until rather close before the Subatlantic phase of instability and that consequently at that time this loamy layer must have been already rather shallow.

The present findings therefore do not present sufficient data to define more precisely, in terms of stable and unstable phases the geological period preceding the Subatlantic phase of slope instability. They, however, do demonstrate that subzone III b represents a local relic of an older loamy layer covering the slopes and that the lowermost part of this layer already occupied its present position when the sphene-containing volconic ash was laid down during the Allerød.

ACKNOWLEDGEMENT

The assistance of Mr. A. Eikeboom, Mrs. Keijzer, Mrs. Van Feggelen, Mr. P. Kok, Mr. C. Snabilié and Ing. H. J. M. Stoltenberg in the laboratory work and in preparing the drawings, photographs and the manuscript is greatly appreciated. The authors are indebted to Dr. A .C. Imeson for correcting the English text.

REFERENCES

Bastin, B., Juvigné E., Pissart A. & Thorez, J. 1974 : Etude d'une coupe dégagée à travers une remport d'une cicatrise de pingo de la Braskvenn. *Ann. Soc. Géol. Belg., T. 97*, 341—358.

Hulshof, O. K., Jungerius, P.D. & Riezebos, P.A. 1968 : A late-glacial volcanic ash deposit in southeastern Belgium. *Geol. en Mijnb. 47*, 106—111.

Jungerius, P.D., Riezebos, P.A. & Slotboom, R.T. 1968 : The age of Eifel Maars as shown by the presence of Laacher See ash of Allerød Age. *Geol, en Mijnb., 47*, 199—205.

Juvigné, E. 1976 : Contribution à la connaissaice de la stratigraphie du Quaternaire par l'étude des mineraux denses transparents de l'Eifel au Massif Central Français et plus particulièrement en Belgique. *Thèse,* Université de Liège.

Kwaad, F. J. P. M. & Mücher, H. J. 1977 : The evolution of soils and slope deposits in the Luxembourg Ardennes near Wiltz, *Geoderma,* 17, 1—37.

Lucius, M. 1957 : L'évolution du relief de l'Oesling (Ardennes Luxembourgeoises). *Tijdschrift Kon. Ned. Aardr. Gen., 74,* 315—323.

Piket, J. J.C. 1960 : Het Oesling landschap rondom Hosingen. *Thesis,* Utrecht.

Pisard, A., Bastin, B., Juvigné, E & Thorez, J. 1975 : Etude génétique palynologique et minéralogique et dépôts périglaciaires de la vallée de la Soor (Haute Fagnes, Belgique). *Ann. Soc. Géol. Belg. T. 8,* 415—439.

Riezebos, P. A. & Slotboom, R. T. 1978 : Pollen analhsis of the Husterbaach peat and its significance for the study of subrecent geomorpholigical events in the Oesling (Luxembourg). In press *BOREAS.*

Riezebos, P.A. & Slotboom, R.T. 1974 : Palynology in the study of present-day hillslope development, *Géol. en Mijnbouw 53,* 436—448.

Ruxton, B.P. 1958 : Weathering and subsurface erosion in granite at the Piedmont Angle, Balos, Sudan *Geol. Mag. VXCV,* 353—377.

Verhoef, P. 1966 : Geomorphological and pedological investigations in the Redange-sur-Attert Area. *Thesis,* University of Amsterdam.