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RELIC STRATIFIED SCREES OCCURENCES IN THE OESLING (GRAND-DUCHY OF LUXEMBOURG), APPROXIMATE AGE AND SOME FABRIC PROPERTIES

P. A. RIEZEBOS

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Cover plate:
Small-scale deformation of stratified screes near Eschweiler (Wiltz)

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ABSTRACT

An attempt has been made to date relic stratified screes deposits at three locations in the Oesling. Because of the absence of contemporaneous floral and faunal remains, an approach primarily based upon the correlation of some phenomena found in these slope deposits with similar ones described and dated elsewhere has been chosen. These phemomena are:

a) Included charcoal particles which were dated by radiocarbon analysis. Unfortunately charcoal particles were found only at one site.

b) Deformations recognised as cryogenetic which were related to similar phenomena roughly dated in sedimentary areas.

c) Included allochthonous heavy-mineral particles of silt sizes which were related to two known and also roughly dated sources supplying them.

The data collected suggest that stratified screes accumulations were formed and reworked throughout the Weichselian or Vistulian (ca. 70.000 - ca. 10.000 yr. BP) comprising the Early Glacial, the Pleniglacial and the Late Glacial. Microscopic observations of samples suggest that their packing, a fabric aspect controlling porosity and permeability, is generally rather "loose" ("open work" fabric). This also applies to layers and beds which in the field were regarded as silt-bearing with an ostensible "matrix supported" fabric. Hence, it is inferred that possible occurences of such deposits in the subsurface of the Oesling also today are bound to affect the hydrological behaviour in the catchment areas.

ZUSAMMENFASSUNG

Man hat versucht an drei Stellen im Oesling erhaltengebliebene, geschichtete Schuttdecken zu datieren. Weil sich keine kontemporären pflanzliche und tierliche Spuren nachweisen liessen, wurde eine Näherungsmethode gewählt, bei welcher man sich hauptsächlich stützte auf eine Korrelation zwischen einigen in diesen "Hangschutten" gefundenen Phänomenen und ähnlichen, an anderen Orten beschriebenen und annäherungsweise datierten, Erscheinungen. Diese Phänomene sind:

a) Im Matrix des Hangschuttes befindliche Holzkohlteilchen. Diese Holzkohle wurde datiert mittels einer Kohlenstoff-14 Analyse. Leider hat man Holzkohleteilchen nur an einer Stelle gefunden.

b) Deformationen, bei welchen die Frostzerrung als Ursache erkannt wurde. Diese Verformungen wurden in einen chronologischen Zusammenhang gebracht mit gleichartigen, annähernd datierten Deformationen in sedimentären Gebieten.

c) Im Feinmaterial des Hangschuttes anwesenden Schwermineralien von Siltgröße. Die Anwesenheit dieser Schwermineralien wurde bezogen auf bekannte Vorgänge, welche in anderen Gebieten ebenfalls annähernd chronologisch eingestuft sind.

Die gesammelte Daten lassen vermuten daß die Ablagerungen dieses Hangschuttes im Weichselian (etwa 70.000 - etwa 10.000 yr BP), welcher Zeitraum das Frühglazial, das Pleniglazial und das Spätglazial umfaßt, gebildet und umgelagert wurden. Mikroskopische Beobachtungen von dünngeschliffenen Mustern suggerieren daß die Packung - ein Aspekt des Gefüges, welcher Porosität und Durchlässigkeit mitbestimmt - sogar in Schichten und Lagen mit einem ziemlich ausgebildeten feinkörnigen Matrix, immer noch locker ist. Daraus kann man folgern, daß etwaige Vorkommen solches Hangschuttes im Substrat des Oeslings, auch heute noch das hydrologische Verhalten in den Einzugsgebieten beeinflussen muss.

RESUME

On a essayé de dater les dépôts résiduels d'éboulis ordonnés (grèzes litées) de trois sites dans l'Oesling. En absence de restes de flore et faune contemporaines à ces dépôts on a choisi une approche basée d'abord sur la corrélation de quelques phénomènes rencontrés dans ces dépôts de pente avec des phénomènes comparables décrits et datés ailleurs. Ces phénomènes sont:

a) Des fragments minuscules de charbon de bois qui ont été datés au moyen de la méthode du carbone-14. Malheureusement ces particules n'ont été rencontrées qu'en un seul endroit.

b) Des déformations reconnues comme des produits d'origine cryogénétique, qui ont été rattachées à des exemplaires comparables trouvés et datés approximativement dans les terrains sédimentaires.

c) Des particules des minéraux lourds allochtones dans les fractions de limon, qui ont été rattachées à deux sources de matériaux connues dont les événements sont datés approximativement.

Les données réunies suggèrent que les grèzes litées ont été formées et remaniées pendant la période de ca. 70.000 à ca. 10.000 BP (Weichselien, Wuermien ou Vistulien) y compris le Weichselien inférieur (Early Glacial), le Weichselien moyen (Pleniglacial) et le Weichselien supérieur (Late Glacial). Des observations microscopiques effectuées sur des échantillons suggèrent que leur tassement (arrangement des particules) - un aspect de la structure qui détermine la porosité et la perméabilité - est généralement assez peu dense. Cela s'applique aussi aux couches et lits considérés au terrain comme siltiques avec une structure montrant des débris grossiers qui flottent dans une matrice de matériaux fins. Par conséquence, on a déduit que des gisements éventuels de dépôts similaires dans le substrat de l'Oesling peuvent influencer encore aujourd'hui le comportement hydrologique des bassins versants.

PREFACE

Stratified screes are a special type of slope deposits and at first sight only a few people will presumably be enchanted at the subject of this study. Even among earth scientists, the number of persons professionally interested in this subject, has never been so impressive. This is rather amazing, as most of the landsurface of the earth is made up of slopes, and a considerable portion of them is covered by loose debris. This material is commonly indicated as slope deposits, although very often from a sedimentological point of view, a like indication hardly can be justified.

True, since the publication in 1937 of SHARPE's "Landslides and related phenomena", in which the then knowledge about waste movements and their effects was compiled, the possible dangerous consequences of loose debris on slopes has been increasingly realised by geologists, advising engineers and contractors of building and excavation activities. Also the necessity of a better and more extensive soil conservation, and the growing employment of permafrost areas in present arctic regions - both related a.o. with the rise of the world's population - have contributed to a greater geoscientific interest in such formations. Hence their properties, behaviour, and influence upon surface processes and slope forms are today a lot better understood, not in the least by the expansion of the science of soil mechanics.

However, they are seldom considered and utilized as sources from which information concerning the historical and modern landscape evolution might be extracted. It is hoped that the work reported here will be seen as a proper illustration of that potentiality, so that this paper might tend to bring that particular quality of slope deposits in the spotlight.

SHARPE, C.F.S. (1937): Landslides and related phemomena. - Columbia Geomorphic Studies II. Sec. Edition, Cooper Square Publishers, Inc. (1968): 137 pp.

1. INTRODUCTION

Stratified screes or grèzes litées are defined by WASHBURN (1937) as "bedded slope deposits of angular, usually pebble-sized rock chips and interstitial finer material". They are commonly found in limestone areas (GUILLIEN, 1964), but occur also on other rock types. BEAUJEU-GARNIER (1952, 1953) reported them on non-metamorphic schists of the Vosges and on crystalline rocks of the Massif Central. WATSON (1965) described them on grauwackes and schists in Wales. SOONS (1962) mentions their occurrence on grauwackes in New Zealand and BOARDMAN (1978) studied these deposits on slates in Cumbria, England.

Studies dealing with their genesis are not so numerous (JAHN, 1960, 1961; MALAURIE et GUILLIEN, 1953; MALAURIE, 1968; PISSART, 1967), and none of them yielded firm evidence for a particular way of origin or a specific mechanism. Also the work of KIRKBY and STATHAM (1975), STATHAM (1976, 1977) and CARSON (1977) shows that much about the formation and the dynamics of debris slopes remains unclear.

The various hypotheses and mecanisms, deduced from the examination of relic deposits and those in course of formation, are associated with the presence of snow and snow patches, subnival wash, meltwater derived from snow, production of rock chips by frost shattering, etc. etc. Stratigraphical considerations support likewise the connection between frost, snow, meltwater and the origin of stratified screes. Hence, their genesis is generally associated with a nivational environment. WASSON (1979), studying recently deposited stratified screes on the slopes in the Hindu Kush, Pakistan, and observing the mechanism of formation today, concluded however that a general interpretation of stratified debris slope deposits as a product of nivational processes may be in error.

Mentions of occurences of stratified screes in the Grand-Duchy of Luxembourg are almost lacking in literature. Only VERHOEF (1966) discusses the Flauchebierg deposit near Vianden, a 9 m thick accumulation. However from descriptions of slope deposits (PIKET, 1960, p. 36 last paragraph) and from published photographs (HERMANS, 1955, photo nr. 5; RIEZEBOS and SLOTBOOM, 1976, fig. 3a) a greater frequency of occurrence may be expected. In adjacent areas of the Belgian Ardennes, and also in the French Ardennes such deposits have been reported from several locations(GULLENTOPS, 1952; MACAR et ALEXANDRE, 1957; SERET, 1963; HUYS, 1964; VOISIN, 1975; etc.).

2. GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

The Oesling is underlain by metarmorphic rocks of Lower Devonian age comprising the Siegenian and Emsian Formations. In the areas where the exposed stratified slope deposits are found, the Upper Emsian forming part of the synclinorium of Wiltz, occurs below the mantle of surface materials (fig. 1). This upper Emsian consists of Schiefer of Wiltz with an established thickness of more than 200 m, and of the Quartzite of Berlé which is mostly less than 10 m thick (KONRAD und WACHSMUT, 1973). These Schiefer of Wiltz are dark-coloured

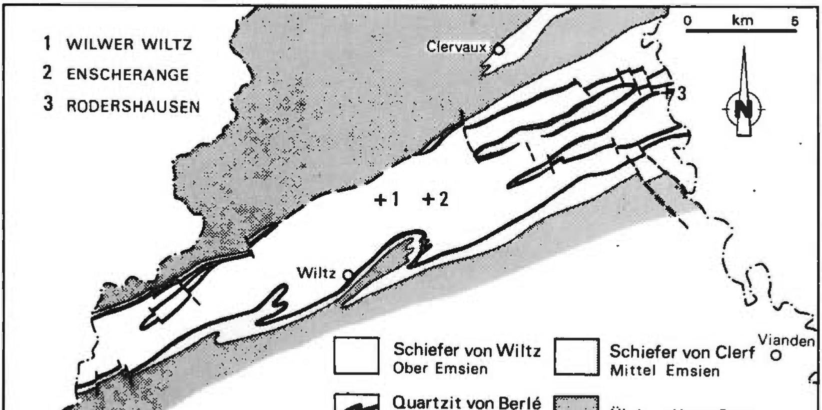

Fig. 1: Map of the Oesling showing the locations (+) where the relics of stratified debris deposits are found, and depicting the extension of the underlying Upper Emsian. Copied from: Carte géologique générale du Grand-Duché de Luxembourg. Echelle 1 : 100.000. Ministère des Travaux Publics, Service Géologique. Deuxième édition 1974.

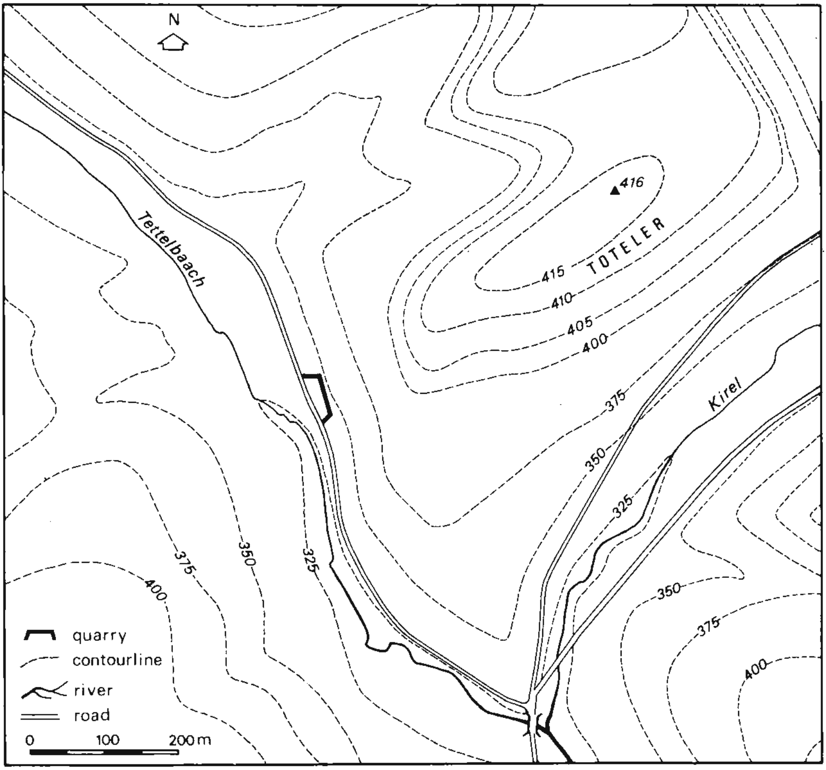

Fig. 2: Contour map with the position of the quarry near Eschweiler. Originally it was probably a road cut which has largely been excavated perpendicular to the road (see also fig. 5 and Plates 1, 2 and 3).

slates containing a little sand. Further they may include thin beds of iron-bearing clay nodules, and they are known to desintegrate rather easily.

The maps in fig. 2, 3 and 4 show the topographical features of the areas where the stratified screes have been exposed in excavations. The first quarry (fig. 2) is in the mantle of rock waste covering locally the foot of a WSW facing slope of the Toteler (416 m). This rock waste was apparently discovered during the last improvement and broadening of the road along the Tetterbach. It has subsequently been mined

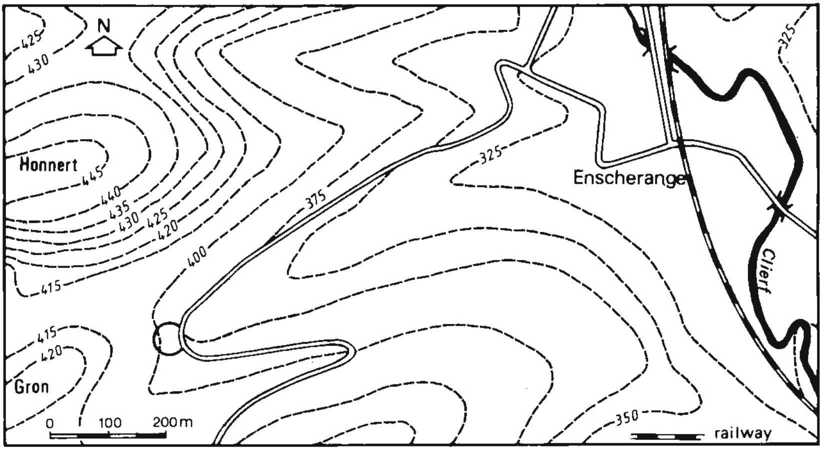

Fig. 3: Map showing the altitudinal pattern around the pit ○ where the stratified screes near Enscherange are extracted. For legend see figure 2.

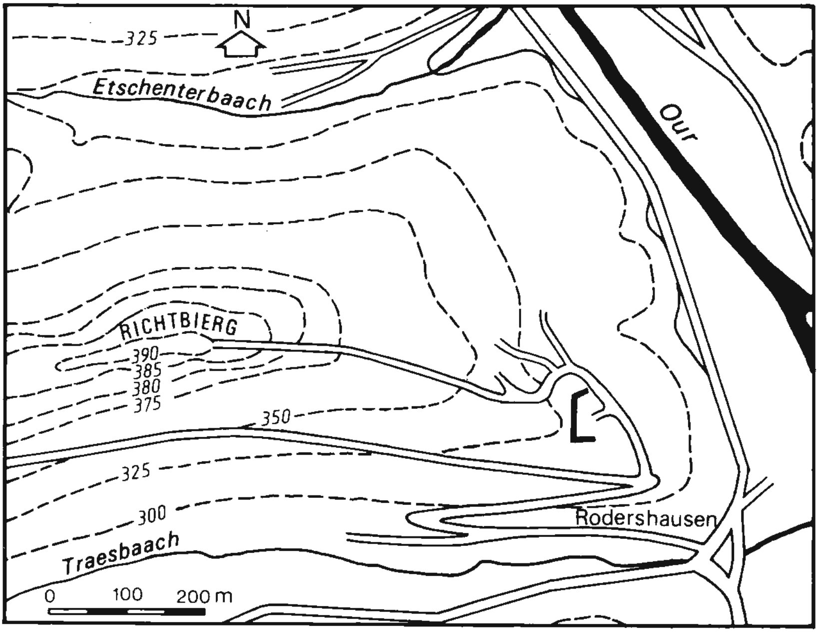

Fig. 4: Ditto around the excavation near Rodershausen. For legend see figure 2.

rather intensively by local people for different purposes. The second excavation (fig. 3) is near Enscherange. This pit uncovers deposits locally reaching a thickness of ca. 20 m. In view of the morphological situation, the stratified deposits here represent probably the head-infill of an ENE extending valley (fig. 3). In the third area these deposits are found in a mining pit in the rock waste on the eastern slope of the Richtbierg near the village of Rodershausen (fig. 4).

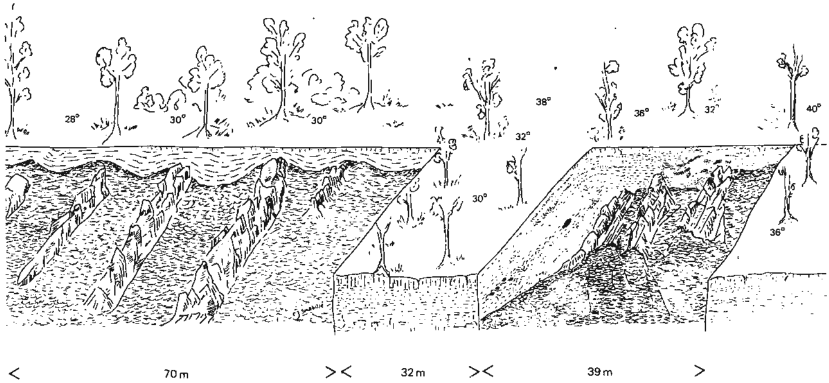

Fig. 5: Outlined summary of the receded road cut in the accumulation at the footslope of the Toteler (see fig. 2). Note the presence of infilled downsloping gulleys, apparently adapted to position and direction of furrows in the underlying hard rock. The complete accumulation next to the road is only left in one block. See also Plate 2.a.

Because of its easy accessibility, emphasis in this study has been placed upon the stratified screes exposed in the quarry near Eschweiler, at a distance of about 4 km north of Wiltz (fig. 2).

3. *PURPOSE OF THE INVESTIGATION*

A common feature shown by the Oesling valleys is the presence of a veneer of angular flat rock fragments underlying the Holocene loamy infills and constituting a rather firm bottom of their river channels. Apparently the eroding force of the modern river courses is not large enough to cut through this veneer. Palynology allowed the dating of the overlying infills (RIEZEBOS and SLOTBOOM, 1974), but the interstitial clay and loam of this layer of flat rock fragments underneath appeared to be sterile in pollen. Also in exposures outside the valleys, residual stratified screes underlying slope deposits of younger age can often be observed (RIEZEBOS and SLOTBOOM, 1976).

In view of the available knowledge about the generating circumstances of stratified screes formation, it is obvious to relate these layers and veneers of flat rock fragments overlain by Holocene alluvial and slope deposits to the Pleistocene. But a more detailed dating is desirable. The Pleistocene period covers a time interval of about 2.5 million years, and even a young Pleistocene age would represent a rather dramatic gap in the infilling of the Oesling valleys. A similar hiatus would also be present in the mantle of loose materials covering slopes and flat portions of the interfluvial areas. Such possible gaps and their magnitudes are not only of interest for a better understanding of the geomorphogenetic development in the past, they may also have far-reaching consequences in considerations on the development and dynamics of the modern Oesling landscapes.

So, although the lack of a solid opinion on the precise genetical circumstances of the stratified screes, by preference would justify an accurate reconstruction of the factors and conditions which gave rise to the origin of these relic deposits near Eschweiler, Enscherange and Rodershausen, the main objective of this study was to obtain more information on their ages. However, as fossil remains in this type of deposit are lacking - even silt-bearing beds appeared to be devoid of pollen - other features of the accumulations had to be used in acquiring this information.

4. PROPERTIES EMPLOYED FOR ESTIMATING THE APPROXIMATIVE AGE

4.1. Radiocarbon dating

The fact that synsedimentary, fossilized floral or faunal remains have not been observed, suggests already that the stratified debris accumulated during cold climates, and seems therefore to support the supposed relationship with the Pleistocene period. Only in the matrix material of one particular bed (see below), exposed in a Rodershausen section, very minute charcoal particles were found. They could be collected in a quantity, sufficient for a radiocarbon analysis.

4.2.Periglacial phenomena

Stratified screes beds can hardly be entitled as sediments characterized by regularity in stacking and extension. This is undoubtedly due to the irregular supply of the rock chips, to the unfavourable nature of their initial deposition sites inducing frequent reworking, to the various transport mechanisms involved (grain flow, talus creep, viscuous debris flow, mass movement, etc.) and possibly also to post-depositional internal dislocations.

Notwithstanding all that, it was possible to recognize disturbances in the stratified debris deposits as products of periglacial processes. The term periglacial refers to environmental conditions characterized by an average annual temperature and rainfall range. PELTIER (1950) e.g. indicates a temperature range of —15° to —1° C, and a rainfall range of 127 - 1397 mm. According to WILSON (1968) the temperature ranges between —12° and +2° C, whereas the precipitation varies between 50 and 1250 mm. Whether permafrost is also a necessary condition as regarded by PEWE (1969) seems to be still a matter of dispute, although recently arguments in favour of this view have been brought forward (VANDENBERGHE and VAN DEN BROEK, 1982, VANDENBERGHE, 1983 a, b).

The observed disturbance phenomena include a clearly developed zone of small- and large-scale involutions, fossil ice-wedges and frost cracks observable in one of the Rodershausen sections (Plate 5.a), a 2 to

3 m thick solifluction bed at the top of the stratified screes in the Enscherange pit (Plate 4.a and b), and further several plicated domains within the grèzes litées accumulation of the Eschweiler quarry (Plate 3.b, fig. 6 and 7).

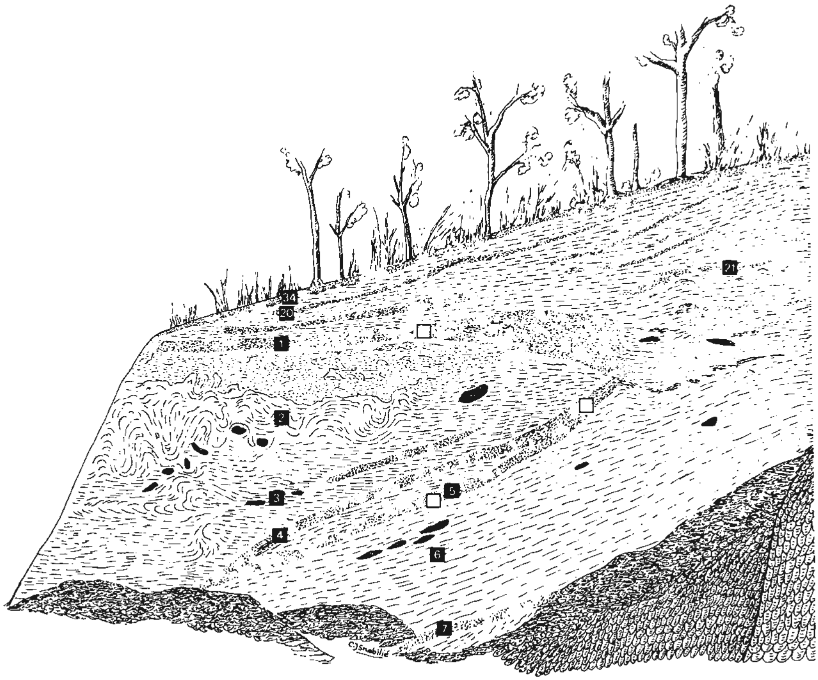

Fig. 6: Artistic representation emphasizing details in the southern wall of the residual block in the Eschweiler quarry (see fig. 5). Notice at the left the plicated domain with an upward reduction in clast size, the inconsistent pattern and irregular nature of "silt-bearing" beds, layers and laminae. Sites where samples come from have been indicated. Open squares refer to some undisturbed samples.

Because of the environmental significance of these periglacial disturbances, several efforts have been made to localize their position in the stratigraphic column (o.a. MAARLEVELD, 1976; GROOTES, 1977;

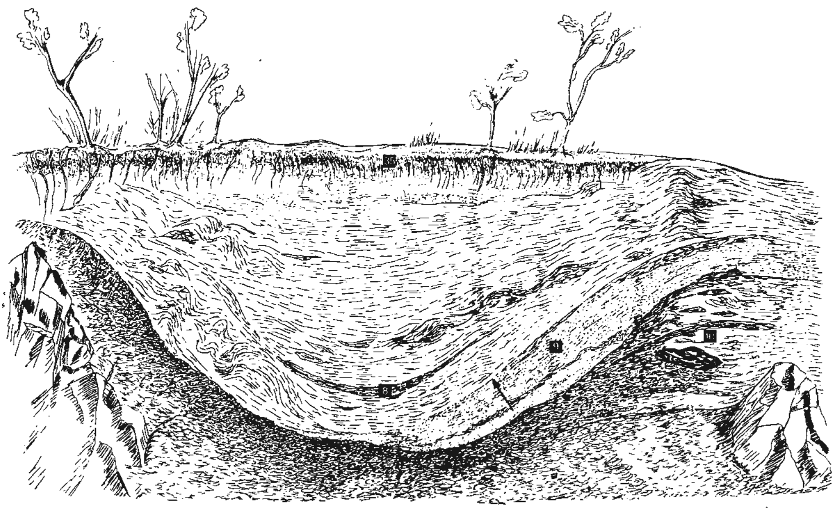

Fig. 7: Drawing of the cross-section of the infilled gulley south of the residual block (see fig. 5) with details and sample positions. Small-scale plications are visible in the left part of the infill. Arrow indicates detail pictured in Plate 2.b.

VANDENBERGHE and GULLENTOPS, 1977; DE MOOR et al. 1978; VANDENBERGHE and VAN DEN BROEK, 1982; DE MOOR, 1983; VANDENBERGHE, 1983 a, b). The most recently published results of these attempts (VANDENBERGHE, 1983 a, fig. 10) have been applied in the present study.

4.3. Compositional characteristics of the associated heavy-mineral concentrates

LUCIUS (1961) has discussed the heavy-mineral compositions of the loose surface deposits in Luxembourg to be constituted of 3 different associations. The first one derives from the parent rocks forming the geological substratum, whereas the other two are connected with volcanic and loess influxes into the Luxemburgian territory in the course of the Quaternary.

As heavy-mineral species representative of the rocks of Devonian and Mesozoic ages are mentioned by LUCIUS (1961): tourmaline, zircon and rutile with in subordinate quantities garnet, anatase and brookite. Epidote and hornblende (brown and green), locally attended with ottrelite and staurolite are thought by LUCIUS as characteristic loess components, while basaltic hornblende, pyroxene and sphene are considered to be representing the volcanic influx.

5. VALUE OF THE INTRODUCED MATERIALS AS CHRONOLOGICAL INDICATORS

5.1. Loess

Although today individual loess strata or local loess deposits are unknown in the Oesling, the work of HEYART (1963) testifies that in the Gutland locally or more extensively, substantial eolian accumulations have been present. VERHOEF (1966, p. 447) also enumerates locations in northern Gutland where pure loess with a thickness less than 150 cm still is occurring at the surface. From several other studies, a.o. those mentioned by LUCIUS (STEFFEN, 1951; HERMANS, 1955; JUNGERIUS, 1958) and from later work, it is clear that characteristic loess heavy minerals are still found intimately mixed with the loose surface deposits in Luxembourg (LEVELT, 1965).

Unfortunately no data are known about the age of the loess deposition. In some adjacent countries as Belgium, Germany and the Netherlands, the main accumulation - apart from some occasional occurrences of very old loess sediments - was taking place during the Saalian (ca. 90.000 - 200.000 yr. BP), whereas also from the Weichselian (ca. 10.000 - 70.000 yr. BP) extensive loess deposits are known. Assuming that in Luxembourg these events have been occurring more or less contemporarily, this knowledge may be utilized in settling the approximate ages of the stratified slope deposits.

Compositional features of the heavy-mineral concentrates have been used to discriminate these sediments chronostratigraphically (VAN DOORMAAL, 1945; GULLENTOPS, 1954, LATRIDOU, 1968; JUVIGNE, 1978b; THIEME et al., 1981; MEES and MEYS, 1984). Pre-Weichselian loess should stand out from Weichselian loess by a lower value (<0.6) of the so called mineralogical index (MI). This MI is Σ green hornblende + garnet / Σ zircon + rutile (JUVIGNE, 1978b).

Recent work, however, suggests that the applied measure MI is not so suited to that purpose (BALESCU and HAESAERTS, 1984; JUVIGNE, 1985).

The underlying idea however, involving that constituents from sediments laid down in a previous glaciation will probably be incorporated, after an interglacial, in airborne deposits originating during a subsequent less extensive glaciation, seems rather sound. Sedimentary petrological work done on Saalian till deposits in the Netherlands (DE WAARD, 1949; RIEZEBOS, 1968) has shown for instance that the various size fractions of the till are rather rich in amphibole particles, and also that in general the amount of amphibole particles is increasing towards the top of the till sections (RIEZEBOS, 1983; RAPPOL and STOLTENBERG, 1985). Exposure of such tills and their associated fluvioglacial sediments at the land surface, under conditions allowing wind erosion, will obviously result in amphibole-bearing eolian deposits elsewhere. Contributions from non-glaciated source areas, however, can never be ruled out, and may interfere with the signal or even obscure it. The eventual effect of both types of source areas in the various compositional aspects of an arbitrary loess deposit, depends finally upon several other factors too, and as a consequence the compositional features are likewise diverse in different regions.

Nevertheless, assuming for the sake of argument that a certain mineral has been exclusively supplied by a glaciated source, than its vertical variation in unreworked loess sections may be considered to reflect the changing contribution of this glaciated source, at least within a limited deposition area. Recent work of MEYS (1985) on Dutch loesses does illustrate this phenomenon. Pleniglacial loess accumulations seem to be marked by 10-35% green amphibole particles in the 30-63 μm heavy-mineral fractions. Early Glacial loesses by 6.5-10%, while Saalian loesses seem to contain less than 6.5%. Therefore, such an approach may offer more perspective for a chronostratigraphical distinction and correlation inside a restricted sedimentation area.

5.2. Tephra

As to the volcanic influx in the Oesling, no individual tephra layers have been encountered until now, nor is the number of eruptions supplying the volcanic clastic material exactly known. From this unfamiliar number of volcanic ash supplies, however one has been found in primary position in some nearby regions being SE-Belgium (HULSHOF et al., 1968), the West-Eifel (JUNGERIUS et al., 1968) and Saarland (JUNGBLUT et al., 1981). It is the well-known and well-dated Late-Allerød eruption of the Laacher See, recently subjected to an extensive study by VAN DEN BOGAARD (1983).

This eruption has probably made the most substantial volcanic contribution to the loose surface deposits in the Oesling, and is additionally easy to recognize since the associated ash-plume(s) supplied abundant juvenile particles of sand sizes. But it is for certain that clastic volcanogenic mineral particles have also been brought into the Oesling before the Late-Allerød Laacher See eruption. They were observed in slope deposits directly underlying the Allerød Laacher See ash near Kirf just east of Luxembourg (JUNGBLUT et al., 1981). Also their occurence in the paleosols of Warneton (PAEPE, 1966) and Rocourt (GULLENTOPS, 1954) of early Weichselian age (JUVIGNE, 1978a), forms firm evidence for the view that more than one ash fall has provided the surface mantle in the Oesling with volcanic particles. But it is not for certain whether they have been introduced directly into the Oesling area by volcanic ash clouds emitted from eruptions. In view of their close association with typical loess components, also in the Luxemburgian surface materials, it never can be precluded that the volcanogenic mineral particles in the loose surface material of the Oesling actually have been supplied as constituents of eolian dusts (TILLMANS and WINDHEUSER, 1980).

In the Pleistocene deposits of the Netherlands, lithostratigraphic units are distinguished - in particular the Formations of Urk and Kreftenheye - which are being characterized by the presence of volcanic augite in their heavy-mineral spectra (DOPPERT et al., 1975). These formations are mainly related with the river Rhine sediments, and cover in time about the last 400.000 year. This implies that theoretically in the course of this period of time airborne tephra or tephra components together with windborne sands and silts might have been accumulating in Luxembourg.

In summary, the inclusion of volcanogenic mineral particles in the stratified screes might indicate them to be younger than ca. 400.000 yr. BP, whereas the attendance of typical loess components might label the slope deposits as younger as ca. 200.000 yr. BP.

6. *DESCRIPTIONS OF THE EXPOSURES*

6.1. Quarry near Eschweiler

A schematic overview of this quarry, which is an excavated road cut, is presented in figure 5. It represents a synoptical impression obtained from the field and numerous photographs. Figures 6 and 7 give more detailed draughts of two sections, parallel and perpendicular to the slope direction, in the heap of rock waste. Several photographs (Plate 1.a and b; 2.a and b; 3.b) testify clearly that use of the term stratified screes is justified. Thickness of the deposit is greatest next to the road, thinning out slope upwards (Plate 1.a). The surface of the underlying hard rock has a very rugged and fretted appearance (Plate 3.a). A system of downwards sloping small ravines or gulleys separated by steep walls is shown (Plate 2.a, fig. 5 and 7). The way in which these have been filled in, is especially demonstrated in the sections, perpendicular to the general slope direction (fig. 5 and 7). Slope-upwards of the quarry the slope angle of the ground surface varies between 26° and 38°.

The deposit consists of angular flat rock fragments reaching diameters of ca. 10 cm. In particular sections in the direction of the slope (fig. 6, Plate 1.b) may display an irregular alternation of finer ostensibly silt-bearing and coarser silt-poor beds. Generally the silt-bearing beds contain smaller and less numerous clasts which show also a less manifest parallel orientation. Boundaries between silt-poor and silt-containing layers may be sharp or diffuse (Plate 2.b).

The coarser beds exhibit in general a partially open work fabric, meaning that the clasts support one another but that some of the voids are partly or entirely filled by particles smaller than the clasts. The former may occur as a sort of silt caps on the latter (Plate 6.a). The silt-bearing beds seem mostly to have matrix-supported fabrics (clasts float in a finer grained groundmass), but probably it often concerns

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Plate 1.a: About W.E. oriented south wall of the residual block of rock waste (fig. 5) at the footslope of the Toteler near Enscherange.

Plate 1.b: View showing at close quarters distribution and position of finer grained and "silt-containing" lenses and layers in this section.

Plate 1.a

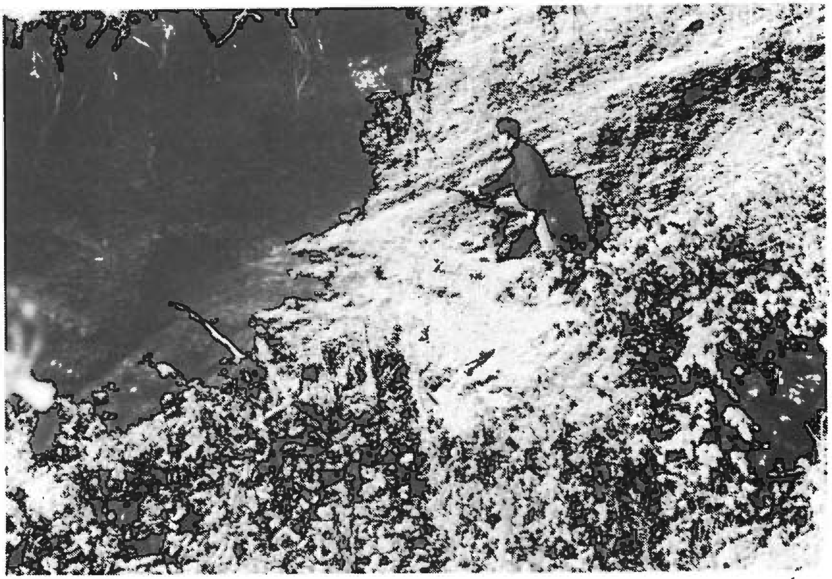

Plate 1.b

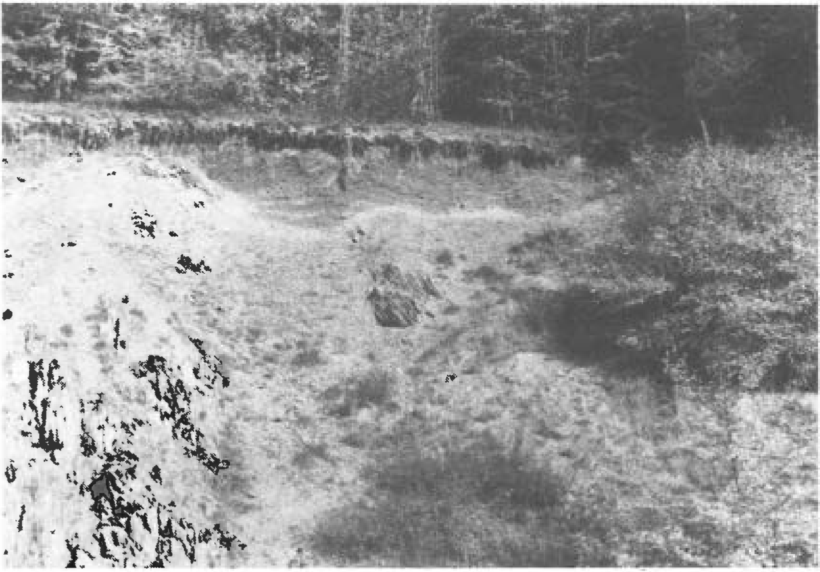
Plate 2.a

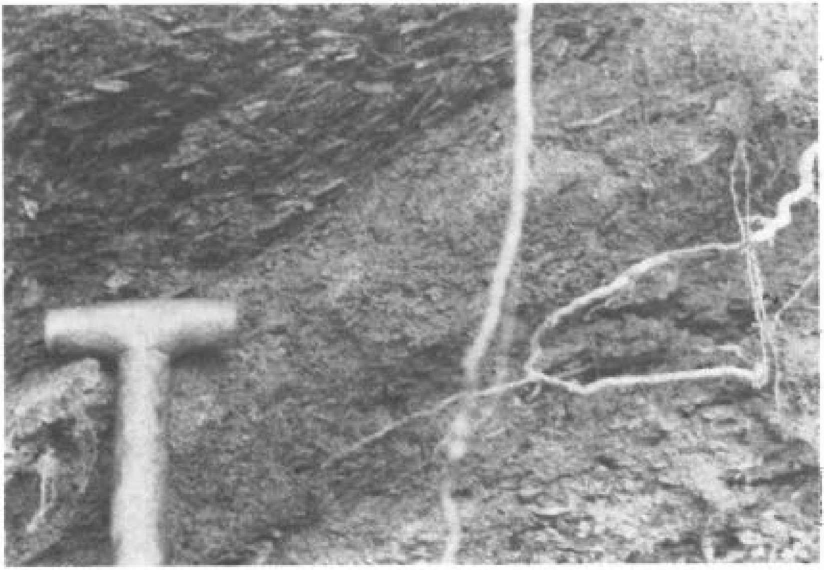
Plate 2.b

also clast-supported fabrics wherein the voids have been filled up by finer particles (Plate 6.b and c). Beds with apparent matrix-supported fabrics hardly exceed 10 to 20 cm thickness, have limited spatial distributions and may display a lens-shaped appearance.

The sections presented in figures 6 and 7 contain plicated domains (Plate 3.b). In the NNW-SSE exposure this sort of disturbance seems primarily to be confined to the beds adjacent to the steep gulley walls (fig. 7). This suggests that the phemomenon here may have been produced by a slight downslope re-allocation of detritus originally deposited with a preferred orientation of the clast axes towards the gulley depression. Thus, no invoke of cryoturbatic processes seems here necessary. In the other section (fig. 6) this phenomenon is more widespread. Here it is found locally over a vertical distance of 2 metres with a manifest decrease of the associated rock fragments upwards (Plate 3.b). There is a considerable difference in slope angle of the beds below (25-30°) and above (4-8°) this disturbed zone (fig. 6, Plate 3.c). The development of the plications is rather chaotic and there is no discernable concurrence between their orientations and the slope angles of under- and overlying beds. So, in this section cryoturbation (congelifluction) seems to be a more plausible explanation. Some of the other features observable in this debris accumualation e.g. manifest erosive contacts, abrupt changes in slope angles of the stacked beds, indicate that considerable reworking has occured.

6.2. Excavation near Enscherange

The pit, uncovering the stratified screes in a valley head near Enscherange (fig. 3) indicates that the protective effect of this particular landform has led to a probably more complete preservation of the accumulated debris. Plate 4.a and c portray the western and northern walls displaying a rather regular and extended stratification, which shows that here ample space has been available during the formation of the

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Plate 2.a: Grèzes litées exposed perpendicular to the slope direction of the ground surface, about north-west of the residual block visible in figure 5. It demonstrates a relationship between the bedding of the infills and the rock furrows beneath.

Plate 2.b: Sudden change from fine- to coarse-grained debris infill in gulley south of the residual block (fig. 5 and 7).

Plate 3.a: Photograph demonstrating the effect of Pleistocene frostweathering on the surface of the exhumed parent rock.

Plate 3.b: Close up of the plicated domain observed in the residual block (see fig. 6). It illustrates also the upward decrease in clast size.

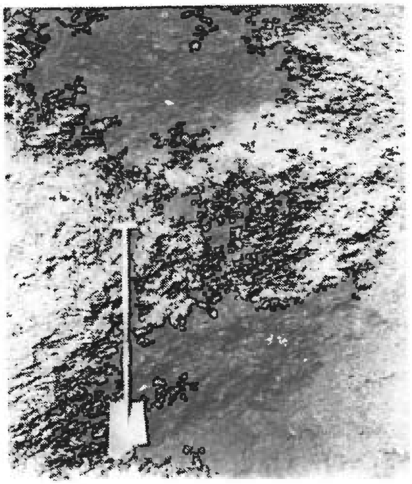

Plate 3.c: Section showing in the residual block of stratified screes a change in dip of the composing beds. At the level of the spade's top is the transition zone characterized by randomly oriented clast inclinations.

Plate 4.a: The pit near Enscherange being more or less circular in plan, photographed from the entrance at the eastern side. In the upper left part, just below the drift bed, outcrop bending (''Hakenwerfen'') is vaguely visible in the top of the stratified debris.

Plate 4.b: A closer view of the outcrop bending. Notice the heterogeneous character of the overlying drift bed.


Plate 4.a


Plate 4.b

individual beds. In the portrayed section of Plate 4.c, the beds are dipping in north-eastern directions with angles varying between about 10° at the top and ca. 30° at the (accessible) base of the deposits. Slope angle measurements at various sites in opposite sections seem to suggest that initially the infilling has been built up by several tongues of debris, each of them coming from different spots slope-upwards.

The stratified screes here are overlain by a ca. 2 to 3 m thick solifluction layer (Plate 4.a and b). Within this bed, domains consisting mainly of loess-like material and "stratified screes parcels" have occasionally been observed. Just below this drift zone, curvatures of the stratified screes ("Hakenwerfer") are in places discernable (Plate 4.b).

Closer inspection however, reveals the stratified appearance to be less regular than it seems to be from a great distance. The horizontal extensions of the individual beds strongly vary, and appear often to be determined by a non-persistent occurence of texture and structure (Plate 4.d). Boundaries between individual beds may be sharp or diffuse, depending upon whether grain size and fabric differences between the succeeding beds are abrupt or gradual. Beds with a greater content of finer particles occasionally occur in clusters. These clusters consist of a rather extensive specimen associated with smaller "satellites" below and above the main one.

Compared with the exposures in the Eschweiler excavation, the outcropping stratified screes in this pit exhibit considerably less beds, which in the field may be described as obvious clast-supported and matrix-supported. Partly this may be ascribed to the generally smaller dimensions of the rock fragments in this excavation. Microscopic observations on samples derived from such beds (see below), however, indicate also that the microscopic fabric does not necessarly complies with

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Plate 4.c: Close up of the nothern segment of the pit. Compared with the sequence in the Eschweiler quarry, the deposits display here a regularly stacked sequence. Going upwards in the section there is a manifest reduction in dip angle of the layers.

Plate 4.d: Example of texture transitions (dashed line) giving primarily rise to the large-scale stratification in the accmulation near Enscherange. In the lower part of the photograph, a sort of slightly developed graded bedding - although irregularly distributed - is perceptible. The white, circular spot is a coin (∅ = 2 cm) for scale.

Plate 4.c

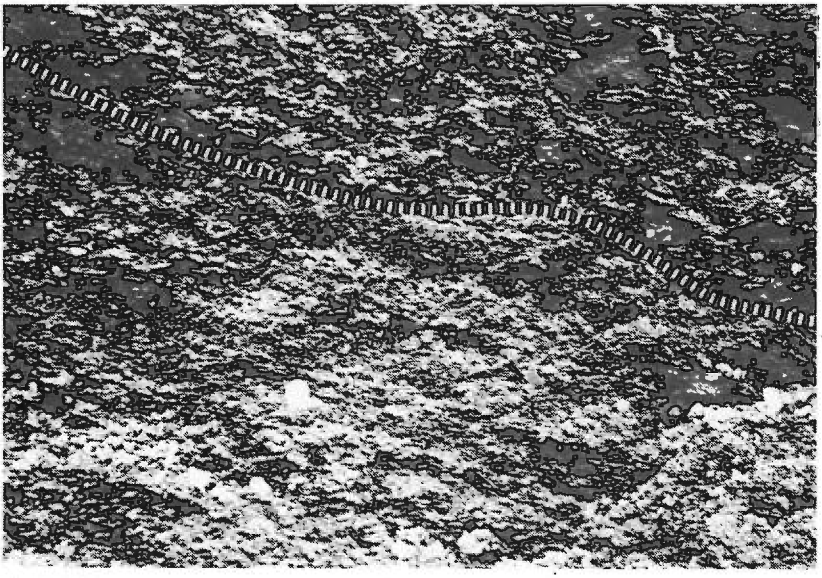


Plate 4.d

the macroscopic definition of the fabric. Open work and partially open work fabrics seem often to be dominating under the microscope in samples taken from layers, which in the field were thought to have a matrix-supported fabric. Their contribution to the clearly perceptible stratification seems therefore to be due to differences in particle size, to the internal arrangement of the clasts (isotropic and anisotropic) and occasionally to a weakly developed grading (positive and negative) as shown in Plate 4.d. This last feature may possibly be a reflection of a seasonal rhythm in supply and/or production of the debris.

6.3. Excavation near Rodershausen

This pit being a two-level specimen (fig. 8) is not in full operation any more. Mining seems to be done only occasionally by local people. The exposures in the NS and EW oriented walls suggest the deposit to be built up in two main units. These are distinguishable in the field as the dips of their composing beds are clearly differently oriented, and as the upper unit is made up of beds with generally a "fresher" appearance.

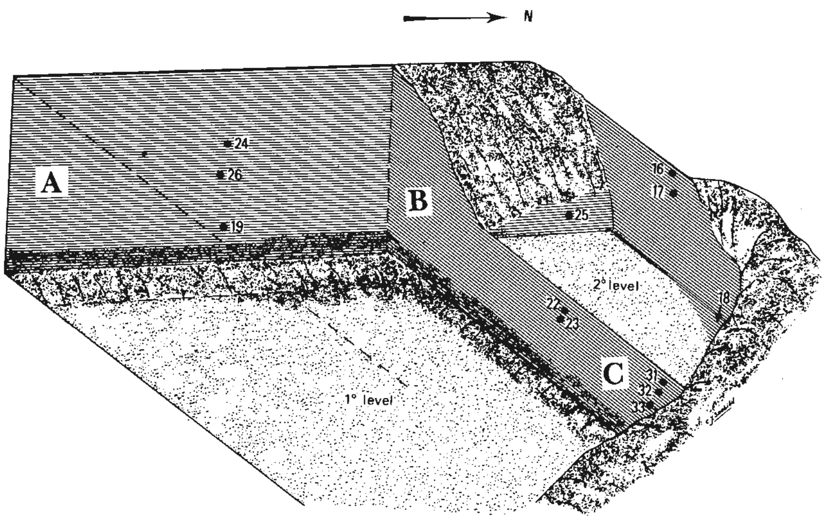


Fig. 8: Skematic outline of the two-level excavation near Rodershausen showing the positions of the sections and further details.

This excavation has been included in the investigation because of two conspicuous phenomena, visible in the sections. The first one is the occurence in the lower unit of a 3 to 4 m thick zone showing large-scale involutions, ice-wedge casts and frost cracks (Plate 5.a). It is only outcropping in the NS exposure, (section A in figure 8). Ice-wedge casts of more than 2 m have been measured, but they are also associated with numerous small frost cracks and several types of involutions. Due to the precipitation of hydrous iron-oxide material at the transition of host rock to cast filling and at the boundary between texturally different debris, they are easily discernable in the field.

The lower unit containing this particular zone has been cut off by a second unit, consisting of beds with a plainly differently oriented dip slope (Plate 5.b, section B in fig. B). In appearance the majority of beds in the upper one bears much resemblance to the stratified screes beds outcropping in the excavation near Enscherange. At its base this unit holds the second striking phemomenon viz. a distinctly more brown-coloured, wedge-shaped, silt-bearing zone with a sharp upper boundary, because it is overlain by an evident open work bed, and a diffuse lower boundary (see C in fig. 8). It does show some field characteristics of a soil, but it has been interpreted as reworked stratified screes material showing an increasing amount of loess-soil material towards the top. Its occurrence was rather limited in this EW section. This soil-like bed was also characterised by the presence of very fine charcoal particles which have been collected for radiocarbon analysis.

Plate 5.a: View of the cryoturbated zone exposed in the lower unit of stratified screes near Rodershausen (section A in fig. 8). The general bedding is slightly inclining to the front, i.e. to the East. Somewhat right of the center of the photograph block-faulting is discernable, a feature often reported in association with ice-wedge formation. This cryogenic zone, reaching locally almost to the top of the section, shows further several deformations most of them probably connected with periglacial conditions.

Plate 5.b: Photograph of the western part of the B-C section in figure 8, showing the upper unit of the Rodershausen accumulation. This unit displays an evidently dipping in northeastern directions.

Plate 5.a

Plate 5.b

7. EXPERIMENTAL PROCEDURES

For radiocarbon analysis minute charcoal particles were sampled from the matrix of the soil-like bed (Rodershausen excavation) by handpicking, and submitted to the Isotope Physics Laboratory, University of Groningen. A fresh outcrop of this bed of ca. 0.5 by ca. 2 m had to be scrutinized carefully, in order to obtain a sufficient quantity of charcoal.

Samples for heavy-mineral analysis were collected at various depths and at specially selected sites in the stratified screes sequences. The $< 500\ \mu m$ material was isolated in sand and silt fractions after separation from the bulk samples. Of each sample at least one silt and one sand fraction were subjected to heavy-mineral separation. A separate examination of the silt- and sand-sized heavy minerals was considered of vital interest for the recognition and the estimation of the relative contributions of the 3 sources discussed above.

Following LUCIUS and his predecessors (see references in LUCIUS, 1961), three assemblages were distinguished in the heavy-mineral spectra obtained by microscopic analysis. Zircon, tourmaline and rutile are considered to be representative of the parent association (PA), epidote and green amphiboles of the supplied loess material and they form together the loess association (LA), whereas pyroxenes, brown amphiboles and sphene summed up are thought to represent the volcanic association (VA). The remaining heavy-mineral species, identified or unidentified, are placed in a rest association (RA).

Further the grain-size distributions were measured in a number of samples. In order to work up an effective separation of the finer particles from the granule- and pebble-sized components, the material was ultrasonically treated in addition to the application of the usual chemical reagents.

Finally, undisturbed samples were taken carefully from a number of special sites in the stratified debris sequences (silt-bearing beds, transition zones between ostensibly silt-lacking and silt-bearing beds, individual pebbles unilaterally covered by smaller particles, the soil like bed, etc.). After impregnation with artifical resins, they were thin-sectioned for microscopic study.

8. *DISCUSSION OF THE COLLECTED DATA*

8.1. Charcoal age and stratigraphic position of the major periglacial phenomena.

The charcoal particles coming from a basal bed of the upper unit of stratified screes in the Rodershausen excavation (see C in fig. 8), were analysed and the resulting age appeared to be more than 47.000 yr. BP (GrN 10178). Because this upper unit truncates the lower set of stratified screes beds unconformably, the lower unit including the zone with ice-wedge casts and involutions, must be much older.

In the Weichselian deposits of Belgium and the Netherlands, two main levels of ice-wedge casts and associated cryogenic involutions are now recognized (VANDENBERGHE and VAN DEN BROEK, 1982; VANDENBERGHE, 1983 a and b; VAN DER MEER et al., 1984 and references cited in these publications). These two levels are thought to represent periods of permafrost (VANDENBERGHE and KROOK, 1981) and chronostratigraphically these periods have been positioned between 20.000-25.000 yr. BP, and between 50.000-65.000 yr. BP (VANDENBERGHE, 1983 a and b).

The radiocarbon age mentioned above precludes the level of 20.000-25.000 yr. BP as a stratigraphically correlative phenomenon. As no evidence of Eemian deposits or soil development has been noticed in the field, it seems obvious to correlate for the time being the cryoturbated zone inside the lower stratified screes unit with the oldest main level of ice-wedge casts having an estimated age of 50.000-65.000 yr. BP.

The Enscherange exposures show (Plate 4.a, b and c) that solufluction produced a 2 to 3 m thick drift bed on the top of the stratified screes. Its very heterogeneous nature displaying "parcels" of stratified debris in different orientations and pockets of rather pure loess-like material, demonstrates for a start that this bed originated when loess already had been introduced in the Oesling. These features suggest further that part of the waste was frozen when moving downwards. The outcrop bending observed (Plate 4.b) just below the base of the drift might suggest that the debris movement, at least at that particular site, initially was slow, so the term gelifluction might be more appropriate than the word solifluction. It is impossible to establish whether the required

Chronostratigraphy			C14-years
HOLOCENE		Praeboreal	10.000
WEICHSELIAN (VISTULIAN)	Late Glacial	Late Dryas Stad	11.000
		Allerød Interstadial	11.800
		Early Dryas Stad	12.000
		Bølling Interstadial	13.000
	Pleni-glacial		29.000
		Denekamp Interstadial	32.000
			37.000
		Hengelo Interstadial	39.000
			43.000
		Moershoofd Interstadial	50.000
		Odderade Interstadial	about 58.000
		Brørup Interstadial	about 65.000
		Amersfoort Interstadial	about 68.000
EEMIEN			

Table 1: Chronostratigraphical outline of the Weichselian (Vistulian) according to VAN STAALDUINEN et al. (1979).

required saturation of the mass waste was due to melting snow and ice, to permafrost conditons or to both (degrading permafrost). But it seems reasonable to suppose that this drift bed started to form at the conclusion of the last cold phase of the Wechselian. In that case this gelifluction bed might be considered more or less contemporaneous with the involutions associated with the upper main level of ice-wedge casts described in the Weichselian deposits of Belgium and the Netherlands (see VANDENBERGHE, 1983a, fig. 10).

The limited occurrence of the deformations in the Eschweiler sections (fig. 6 and 7) and their small dimensions (Plate 3.b), seem to make their cryogenic nature somewhat more suspect, and their possible value as stratigraphic marker therefore more questionable. The complicated and rather chaotic build up of the stratified screes at this location, as especially is illustrated in figures 6 and 7, with opposing angles of recognizable beds or layers and gulley erosion in previously deposited screes, points to a substantial local reworking, associated or otherwise with the production and deposition of fresh screes material. In the section (fig.6) where the convolutions would be mostly qualified as cryoturbatic, the plicated domain is below a manifest erosive contact of rather local nature. In the upper part of this domain the stratification displays a sort of slight convolute bedding (Plate 3.b), whereas in the lower part the axial planes of the much more irregular folds are clearly subhorizontal. Gravity slumping, overloading or drag occasioned by overriding material, possibly related with periglacial circumstances, might for instance have caused the structures or intensified existing ones. So, restricted occurences of features interpretable as products of cryoturbation, may be used as arguments in favour of a periglacial environment. But when their limitation in space can also be explained as local remnants of a cryoturbated zone which have escaped from later reworking, a non-periglacial origin of the deformation structures cannot be precluded.

Recapitulating, it may be concluded on the basis of the radiocarbon age and the positions of the most evident periglacial phenomena in the sections, that the lower unit of stratified screes in the Rodershausen excavation dates somewhere from the Early Glacial, while the upper unit is younger and probably of Pleniglacial age, just as the stratisfied debris exposed in the Enscherange excavation (table 1). The information discussed thus far has no sufficient indicative value for an approximate datation of the accumulations near Eschweiler.

8.2. Heavy-mineral data

In table 2 the heavy-mineral scores have been summarized. They demonstrate that, when sand-sized heavy minerals are observed in the samples, these mineral species belong almost exclusively to the VA. The data further fail to show a close quantative connection between the VA particles in the sand and silt fractions analysed (fig. 9). This figure also suggests that the majority of the coarse silt fractions primarily consists of PA and LA particles. A triangular plot of the silt-sized PA, LA and VA values from table 2 confirms this suggestion, and illustrates that the 32-53 μm heavy-mineral fraction is actually dominated by LA and/or PA (fig. 10).

The sampled materials containing in their sand fractions the VA species, have incorporated the tephra produced by the Laacher See eruption. Therefore, their maximum age is about 11.000 yr. BP. A number of the samples in table 2 have been plotted in the sections (fig. 6, 7 and 8). Figure 11 presents a schematic overview of the relative positions of all the samples in table 2. It illustrates which portions of the accumulated debris are older, more or less synchroneous, or younger than the ca. 11.000 yr. BP Laacher See eruption.

In the Rodershausen and Enscherange outcrops the sand-sized VA particles occur in the ground-surface materials (samples 11, 13 and 16), and at depths of about 50 cm in the gelifluction bed (samples 29 and 30). This indicates that not only the stratified screes at these sites but also the major part of the Enscherange gelifluction bed came into being before ca. 11.000 yr. BP. In the Eschweiler excavation however, the sand-sized VA particles have been established, except in ground-surface materials (samples 34 and 35), also in the gulley infill of the section depicted in figure 7 (samples 8 and 9) and in the upper part of the accumulation exposed in the residual block section (samples 1, 20 and 21). This does not only support the field evidence that here the stratified debris deposits have strongly been reworked. It also testifies that stratified screes have been (re)deposited after the Allerød eruption

It is conspicuous that in contrast with the ground-surface samples, those (nrs. 1, 8 and 9) from depths of more than 1 m below the surface, have much higher VA values in the coarse-silt fractions (table 2, fig. 10). This strongly suggests that the last samples derive from levels in the accumulation, which are more or less contemporaneous with the volcanic ash deposition. When tephra-enriched materials remain for a long period of time at the surface, one of the obtained effects in the Oes-

	Sample nr	LA	PA	VA	RA	LA	PA	VA	RA
		32 - 53 μm				105 - 210 μm			
Eschweiler	34	32.5	34.0	8.0	25.5	1.5	—	97.5	1.0
	35	25.5	47.5	10.0	17.0	—	—	99.5	0.5
	21	54.0	26.0	4.0	16.0	—	—	100	—
	20	60.0	13.5	12.0	14.5	—	—	100	—
	1	14.5	45.0	25.0	15.5	—	—	100	—
	2	22.5	60.1	1.5	16.0	—	—	—	—
	3	26.0	50.0	2.0	22.0	—	—	—	—
	4	42.0	43.0	2.0	13.0	—	—	—	—
	5	23.0	54.5	2.5	20.0	—	—	—	—
	6	25.0	47.0	5.0	23.0	—	—	—	—
	7	35.0	50.5	1.0	13.5	—	—	—	—
	8	19.5	41.0	23.0	16.5	—	—	100	—
	9	9.5	26.0	56.0	8.5	—	—	100	—
	10	23.5	43.0	2.5	31.0	—	—	—	—
Enscherange	11	50.5	24.5	7.5	17.5	—	—	100	—
	12	52.5	22.5	3.5	22.0	—	—	—	—
	13	40.5	20.5	8.0	31.0	—	—	100	—
	14	58.0	20.0	3.5	18.5	—	—	—	—
	15	61.5	14.0	6.5	18.0	—	—	—	—
	27	36.5	33.5	3.5	26.5	—	—	—	—
	28	51.5	29.0	5.0	14.5	—	—	—	—
	29	61.5	14.5	4.0	20.0	3	42	52	3
	30	68.0	22.5	2.5	7.0	1	—	99	—
Rodershausen	16	50.5	21.5	5.5	22.5	—	—	100	—
	17	58.5	20.0	2.5	19.0	—	—	—	—
	18	34.0	35.5	2.5	28.0	—	—	—	—
	19	37.5	33.5	2.5	26.5	—	—	—	—
	22	42.5	35.0	—	22.5	—	—	—	—
	23	40.0	32.5	0.5	27.0	—	—	—	—
	24	30.0	40.0	0.5	29.5	—	—	—	—
	25	53.5	26.0	2.5	18.0	—	—	—	—
	26	42.5	36.5	0.5	20.5	—	—	—	—
	31	17.0	69.5	1.0	12.5	—	—	—	—
	32	30.5	51.5	1.0	17.0	—	—	—	—
	33	17.5	68.5	—	14.0	—	—	—	—

Table 2: Distinguished associations VA, LA, PA and RA expressed in grain percentages of the isolated heavy-mineral concentrates from the 32-53 μm and the 105-210 μm fractions.

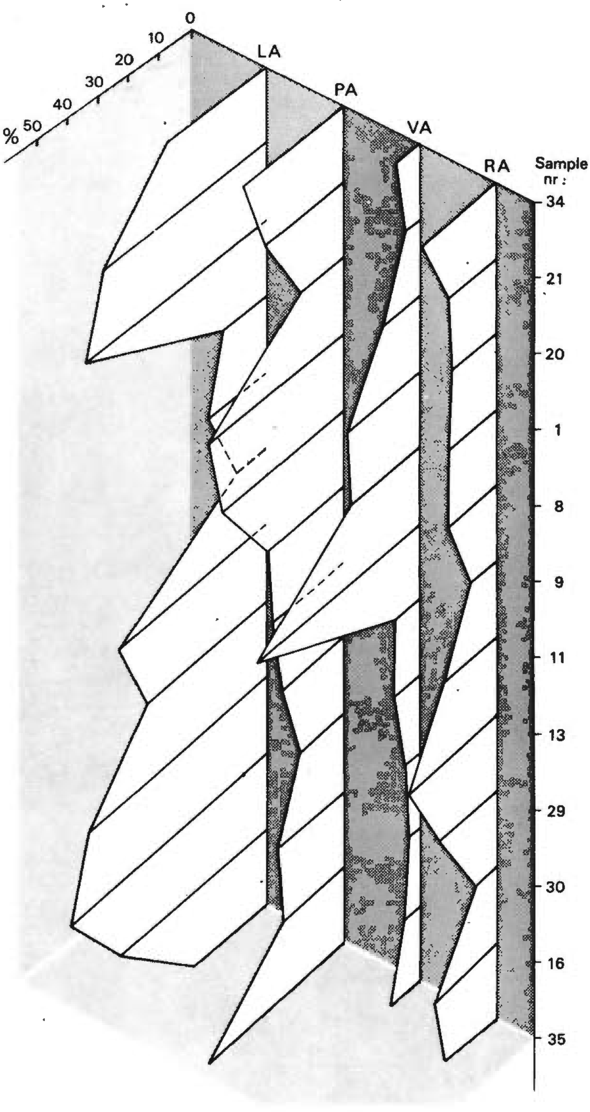


Fig. 9: Diagram showing the mutual proportions of LA, PA, VA and RA in those samples where in the 105-210 μm heavy minerals are almost exclusively made up of the VA (see table 2).

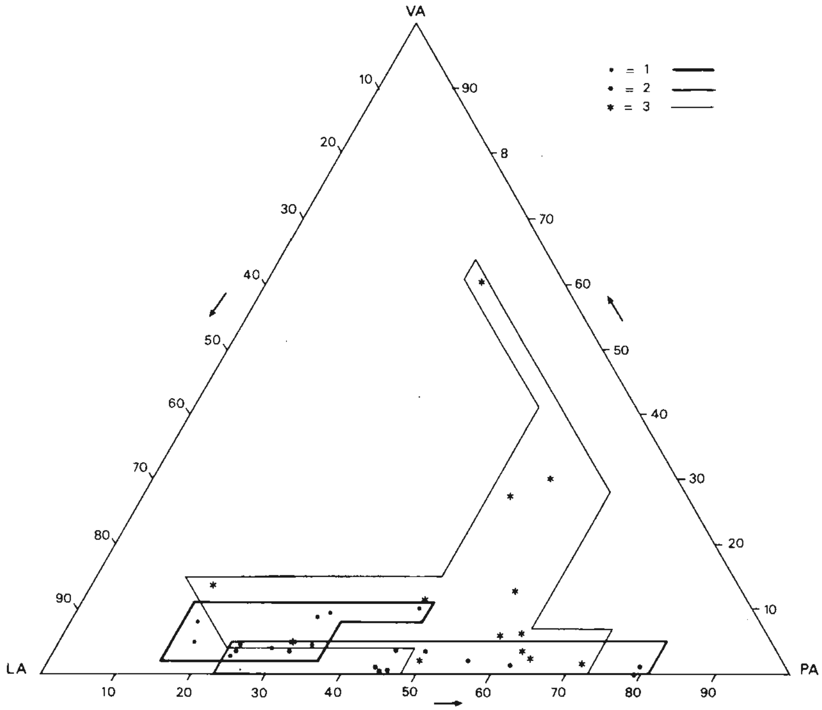


Fig. 10: Triangular plot demonstrating that in the 32-53 μm fractions LA and PA are the dominating associations in the heavy-mineral concentrates. In this plot *(3) indicates positions of the Eschweiler samples, ★(2) those of the Rodershausen, and •(1) those of the Enscherange specimens.

ling is apparently a reduction of the silt-sized ash constituents (compare for instance samples 34 and 35 with 1, 8 and 9 in table 2).

Further it is remarkable that in several stratified screes samples silt-sized orthopyroxenes have been observed (table 3). This sort of pyroxene has never been reported as an essential juvenile constituent of the Allerød Laacher See ash (VAN DEN BOGAART, 1983), although it may be found admixed with these juvenile Laacher See components in reworked rock material (RIEZEBOS and SLOTBOOM, 1976). However, it has been recognized as a probably characteristic heavy-mineral of older

Sample	Brown amphibole	Clinopyroxene	Orthopyroxene	Sphene	Green amphibole	Epidote group	Zircon	Rutile	Tourmalin group
1	6.5	1.5	—	15.0	3.0	11.5	34.0	9.5	1.5
2	0.5	—	—	1.0	6.5	16.0	45.5	9.0	5.5
3	—	—	—	2.0	6.7	19.3	39.2	8.0	2.7
4	—	—	—	2.0	10.5	21.5	31.5	8.0	3.5
5	—	—	—	2.5	6.0	17.0	41.5	10.0	3.0
6	—	—	—	4.9	9.8	15.3	38.3	6.7	1.8
7	—	—	—	1.0	14.0	21.0	31.5	15.0	4.0
8	10.2	2.5	—	10.2	5.0	14.4	30.8	6.3	3.8
9	23.3	9.5	—	23.4	4.1	5.0	21.9	2.3	1.8
10	—	0.5	—	2.0	8.5	25.0	32.0	9.0	2.0
11	3.0	1.0	1.0	2.3	21.3	19.0	8.0	4.7	11.7
12	—	0.3	0.3	3.0	26.3	25.7	4.7	4.7	13.0
13	4.7	0.7	0.3	2.3	18.0	35.7	6.3	5.3	8.7
14	0.3	—	—	3.0	23.0	35.0	8.7	5.0	6.0
15	—	0.7	1.7	4.3	24.7	36.7	4.0	2.7	7.3
16	2.0	1.3	0.7	1.3	20.3	30.3	8.3	3.0	10.3
17	0.3	—	0.3	2.0	26.3	32.0	7.3	2.0	10.7
18	—	—	0.7	1.7	5.0	29.0	11.7	3.0	21.0
19	—	0.3	0.3	1.7	2.3	35.3	13.7	3.7	16.0
20	3.0	1.7	0.3	7.0	21.0	39.0	5.0	3.3	5.3
21	2.0	0.3	—	1.3	18.0	36.3	9.3	3.0	13.0
22	—	—	—	—	6.3	36.0	5.3	7.3	22.3
23	—	—	—	0.3	5.3	34.7	10.7	4.7	17.0
24	—	0.3	—	—	3.3	27.0	16.7	5.7	17.7
25	0.3	0.3	—	2.0	15.7	38.0	11.0	7.0	8.6
26	—	—	0.3	0.3	5.0	37.7	9.3	7.3	20.0
27	—	—	0.5	3.0	16.0	20.5	5.5	2.0	26.0
28	2.5	—	1.0	1.5	21.0	30.5	3.0	3.5	22.5
29	—	—	—	4.0	26.0	35.5	4.0	6.0	4.5
30	—	—	—	2.5	30.5	37.5	5.0	4.5	5.5
31	—	—	—	1.0	1.5	15.5	52.0	11.0	1.5
32	—	—	—	1.0	3.5	27.0	41.0	6.0	5.5
33	—	—	—	—	1.5	16.0	53.0	13.0	2.5
34	3.5	1.0	—	3.5	6.0	26.5	22.5	6.5	5.0
35	5.0	3.0	—	2.0	4.0	21.5	31.5	11.5	3.5

Table 3: The heavy-mineral compositions of the coarse-silt fractions (32-
ralogiacal index» (MI) - see text - has been calculated.

Garnet group	Brookite	Anatase	Sillimanite	Kyanite	Staurolite	Andalusite	Apatite	Chloritoid	Rest group	Mineralogical Index (MI)
4.0	—	11.0	—	—	0.5	—	—	—	—	0.1
4.5	—	11.5	—	—	—	—	—	—	—	0.2
13.4	—	8.0	—	—	0.7	—	—	—	—	0.4
9.5	—	11.5	—	—	1.0	—	—	—	1.0	0.5
7.0	—	12.0	—	—	1.0	—	—	—	—	0.2
7.3	—	12.9	1.2	—	1.8	—	—	—	—	0.3
3.0	—	9.0	—	0.5	0.5	0.5	—	—	—	0.3
4.3	—	9.4	—	3.1	—	—	—	—	—	0.2
4.5	—	2.7	1.0	—	0.5	—	—	—	—	0.3
6.5	—	11.0	0.5	0.5	2.5	—	—	—	—	0.3
1.3	—	12.3	0.7	0.7	1.3	—	—	1.3	0.3	1.7
4.7	—	13.7	1.0	1.0	1.0	0.3	—	0.3	—	3.3
1.7	—	11.0	0.3	1.7	0.7	0.3	—	2.3	—	1.7
4.3	—	8.0	0.7	0.7	2.0	1.3	0.3	1.3	0.3	1.9
3.3	—	10.7	—	1.0	1.0	—	—	2.0	—	4.1
1.0	—	16.0	0.7	1.3	1.7	0.7	—	1.0	—	1.8
1.3	—	11.7	0.7	1.0	3.3	—	—	1.0	—	2.9
1.0	1.0	22.0	—	1.0	1.0	0.3	—	1.7	—	0.4
0.7	1.0	21.7	0.3	0.3	1.7	0.7	—	0.3	—	0.1
1.0	—	8.7	0.7	0.3	1.3	0.3	—	1.7	0.3	2.6
2.0	—	11.3	0.3	0.7	0.7	0.3	—	1.3	—	1.6
0.7	1.3	15.7	0.3	1.7	1.0	—	—	1.7	0.3	0.5
—	—	24.3	0.7	0.7	1.0	—	—	0.7	—	0.4
1.3	0.3	23.3	1.3	1.3	3.0	—	—	0.7	—	0.2
2.3	—	11.0	0.7	0.3	2.0	0.3	—	1.0	—	1.0
0.3	—	14.0	0.7	0.3	2.7	0.7	—	1.3	—	0.3
1.5	0.5	20.0	0.5	1.0	1.0	—	1.5	0.5	—	2.3
2.0	—	9.0	—	—	0.5	—	2.5	—	0.5	3.5
3.5	—	14.0	—	—	1.0	—	—	1.5	—	2.9
4.5	—	7.5	1.0	—	0.5	—	—	1.0	—	3.6
0.5	—	9.0	—	1.0	2.0	—	—	—	—	0.0
—	—	15.0	—	—	0.5	—	—	0.5	—	0.0
—	—	12.0	1.0	—	1.0	—	—	0.0	—	0.0
1.0	—	22.5	—	1.0	1.0	—	—	—	—	0.2
1.5	—	14.5	—	0.5	1.0	—	—	—	0.5	0.1

53 μm) from the grèzes litées samples. On the basis of these data the «mine-

ash falls as the socalled "tuf de Rocourt". Age estimations of these older ash(es) range from the Early Glacial (GULLENTOPS,1954) up to the Pleniglacial (HAESAERTS et al., 1981).

On the basis of the established VA distributions, it may be inferred that the formation of the stratified slope deposits near Rodershausen and Enscherange predates the Laacher See eruption of ca. 11.000 yr. BP, while those near Eschweiler were formed before and after this event.

The LA heavy-mineral particles appear to vary between 9.5% and 68% of the concentrates (table 2). This demonstrates either that loess already had been introduced into the Oesling territory, or that it was in the process of being introduced when the rock chips were originating and accumulating on the slopes. Attemps to date the LA more closely, or to distinguish possible chronostratigraphically different contributions, by calculating the MI using the data in table 3, seem at first sight not so succesfull (table 3). Samples, which due to their VA values must be looked upon as of Late Glacial age or even younger (see e.g. sample nrs. 1, 8, 9, 34 and 35) appear to have a MI smaller than 0.6 (table 3), and should consequently to have be classified as Saalian (JUVINGNE, 1978b). Figure 11 shows that the application of MI as sole criterion labels all the Enscherange samples, and additionally the nrs. 20 and 21 from Eschweiler and the nrs. 16, 17 and 25 from Rodershausen as Weichselian.

Because the use of the MI seems to yield contradictory results, an effort was made to employ green amphibole percentages as a dicriminating criterion (MEIJS, 1985). This author, who used that property in Dutch loess sections, could propose a rather detailled subdivision of these loesses. It speaks without saying the percentages mentioned and employed by MEIJS (1985) for the Dutch loesses, cannot simply be applied in the Oesling. Also it is obvious that possible dicriminating values, applicable for the Oesling area, cannot be settled on the basis of the present number of samples.

Comparison of the green amphibole percentages (table 3) in the investigated samples with their tentatively attributed chronostratigraphic positions, seems to suggest a sort of systematical connection, at least for the Rodershausen and Enscherange localities. The lower unit in Rodershausen ascribed to the Early Glacial has low green amphibole contents (samples 19, 24 and 26), just as the basal beds of the upper unit (samples 18, 22, 23, 31, 32 and 33) of supposed Pleniglacial age.

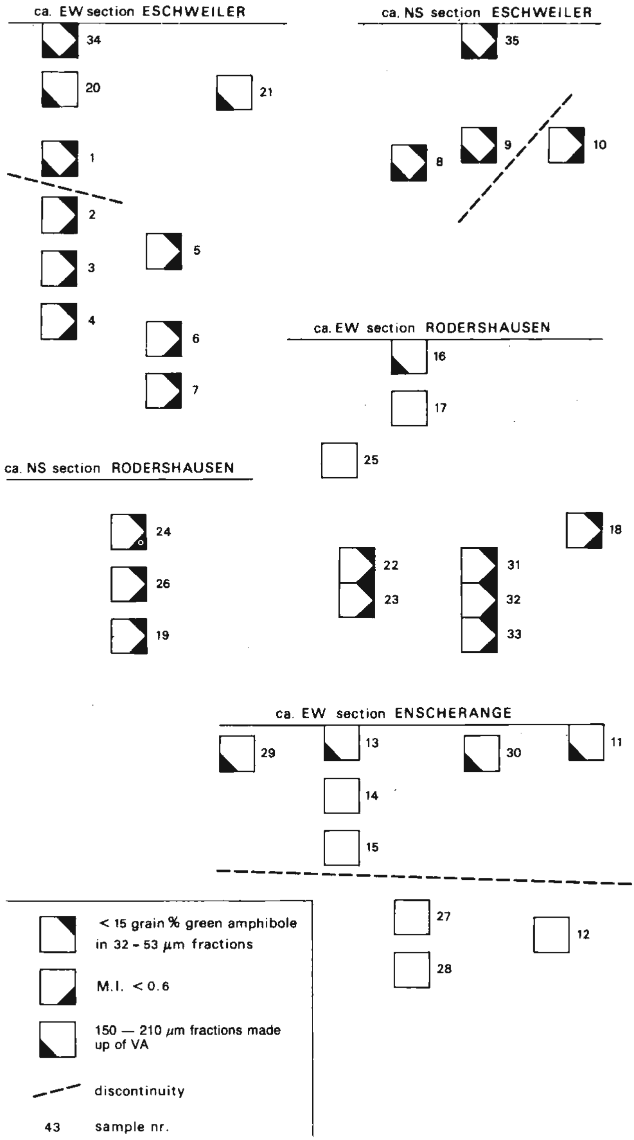


Fig. 11: Summary of the compositional aspects of the samples used, and their relative arrangements in the sections. The dashed lines represent the major erosion contacts.

Upwards in this unit, however, the percentages are much higher (samples 16, 17 and 25). Even sample 16 derived from ground-surface material and obviously displaced and redeposited after ca. 11.000 yr. BP during the Late Glacial or Holocene forms no exception. Also the stratified screes in the Enscherange pit, which are thought to date from the Pleniglacial, seem to be characterized by high percentages as evidenced by the sample outcomes (nrs. 11, 12, 13 14, 15, 27, 28, 29 and 30). Likewise here the surface samples (nrs. 11, 13, 29 and 30) containing the sand-sized tephra components of the Laacher See eruption, and thus (re)deposited after ca. 11.000 yr. BP, continue to show this feature. So the stratified screes development from (presumably) Early Glacial up to and including Late Glacial seems to have been accompanied with a perceptible increase of a characteristic constituent of the associated LA (fig. 11).

The situation in the Eschweiler quarry is more complicated. If it is deduced from the observations discussed above, that stratified slope deposits formed during the maximum cold phase of the Pleniglacial, are associated with LA's bearing more than 15% green amphibole particles, in this quarry only two samples (nrs. 20 and 21) come up to this requirement. Their position, however, in the exposure (fig. 6 and 11) definitely precludes such an age. The same applies to the samples 1, 8, 9, 34 and 35 having green amphibole percentages of 3.0, 5.0, 4.1, 6.0 and 4.0 respectively. According to these percentages they could be of Early Glacial age, but actually they are absolutely of Late Glacial or even early Holocene age. The green amphibole percentages in the remaining samples of Eschweiler range between 6.0 and 14.0, by which the samples 4,7 and 10, occupying the lowest positions in the sections, contain 10.5, 14.0 and 8.5% respectively (table 3).

If indeed the growing incorporation of green amphibole in loess, successively deposited in the course of the Weichselian, has been a continuing phenomenon in the Oesling too, the lacking registration of this feature in the Eschweiler accumulation may perhaps be explained by a frequently associated action of reworking processes at this locality. Mixing of Early Glacial, Pleniglacial and Late Glacial screes might have occasioned the seemingly unsystematic green amphibole abundances. The available field evidence does not contradict such an explanation.

Summing up, by employing field data, one single radiocarbon dating, included periglacial phenomena and incorporated volcanic and eolian products, the chronostratigraphic ages of some stratified screes accumulations have been assessed, be it rather inaccurately. Nevertheless, these rather inaccurate chronostratigraphic positions do not seem to be fully incompatible with the current idea that throughout the Weichselian airborne silts might have become increasingly richer in green amphibole. This is striking, in particular when it is realized that:

1) the development of a slope deposit like stratified screes usually takes place discontinously in time and space;

2) these deposits are liable to several sorts of reworking and therefore of a rather ephemeral nature;

3) the data have been extracted from a few relic accumulations, in which probably the chronological record is also incomplete.

Thus if this relationship is real, than several deviations in the Weichselian record of stratified screes would be natural. Moreover, permanent or temporary changes in dominant wind directions, coupled with exposures of non-glaciated source areas, may have resulted in obscuring this effect temporarily or permanently even in pure loess deposits.

8.3. Particle-size distributions

Distributions have been measured in the smaller than 2 mm fractions from 18 stratified screes samples (nrs. 1-11 and 22-28). In a triangular diagram the established sand, silt and clay contents have been plotted (fig. 12). The outcomes do not show marked differences in silt contents between those samples, which were collected from beds, denominated in the field as silt-bearing and silt-poor. Comparison of the samples 1 and 2 (see fig.6) shows that the so-called silt-containing beds have at the most twice the amount of the so-called silt-poor beds.

Similar data, obtained from a number of samples, which were taken from the uppermost 50 cm of the surface layer at several interfluvial and valley sites in the Oesling, have also been plotted in this diagram. This second group coming from loose material overlying the Emsian as well as the Siegenian Formations, displays on the average clearly

Plate 6.a: Clast carrying a "cap" of finer debris. Length = 13 cm. It was carefully collected at a depth of about 3.0 m below the surface in the exposed southern wall of the residual block (fig. 6, Plate 3.c).

Plate 6.b: Thin-sectioned upper boundary of a fine-grained lamina. Length = 10 cm. Depth ca. 3 m below surface in the ca. east-west section of the Eschweiler quarry (fig. 6).
Notice that in this example the textural diversity with the overlying coarser material seems to be caused by a difference in average clast size, by a difference in interstitial infill, and possibly also by a less distinct parallel orientation of the clasts in the fine-grained lamina.

Plate 6.c: An irregular transition from a relatively coarse lamina to an ostensibly finer-gained one inside the "silt-bearing" bed that overlies the plicated domain in figure 6. Length = 12 cm. Depth ca. 1.30 m below surface. Here the change seems primarily to be occasioned by a denser development of the matrix.

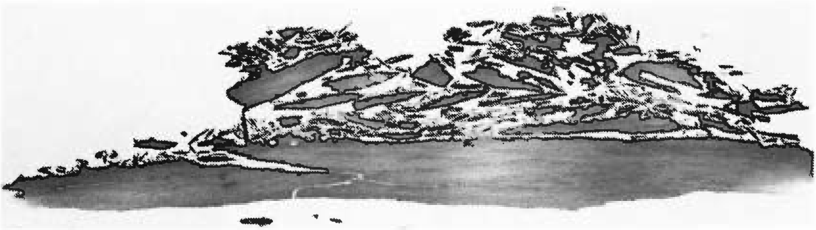


Plate 6.a

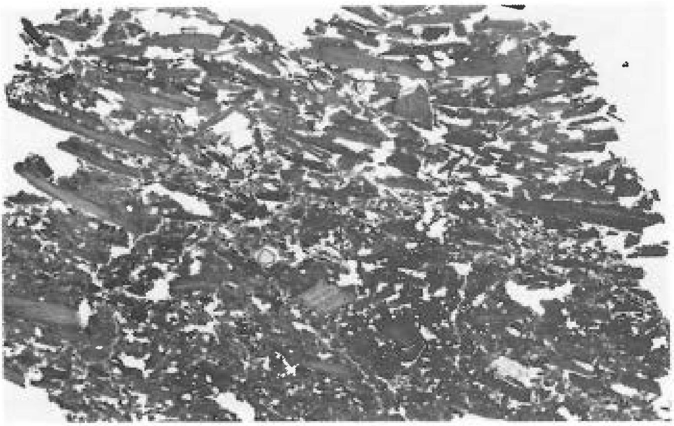


Plate 6.b

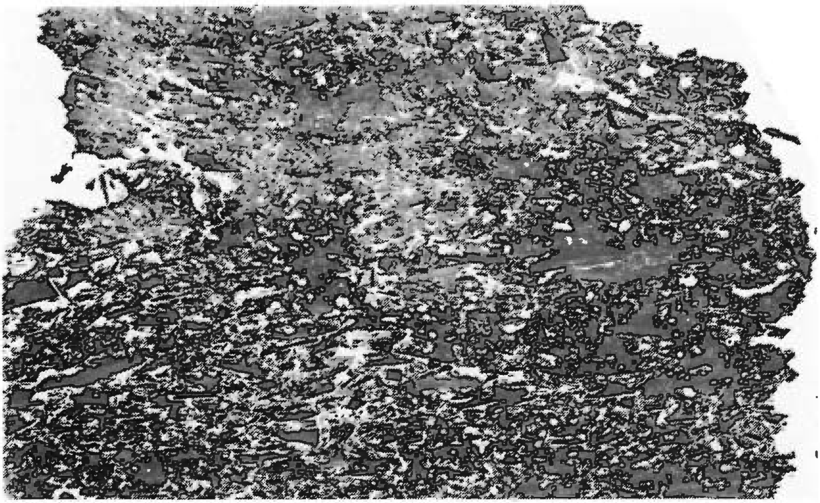


Plate 6.c

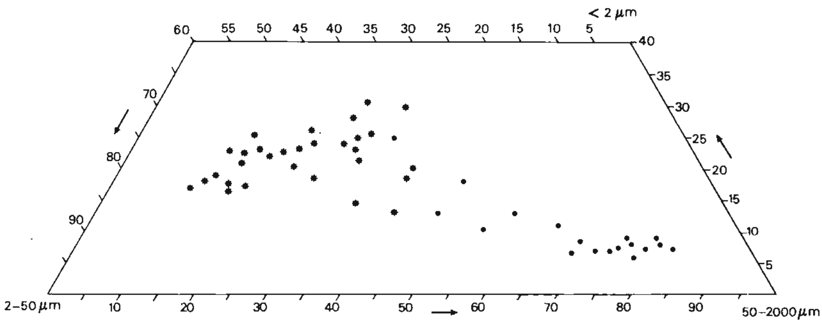


Fig. 12: Plot comparing sand, silt and clay abundances in a number of stratified screes (•) and other surface samples (*). A clustering according to the two groups can be distinguished.

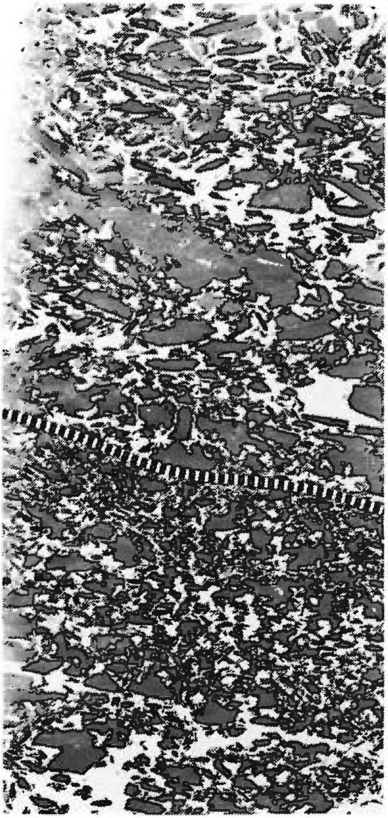
higher silt and clay abundances than the stratified screes group (fig. 12). Nevertheless, the plot still suggests a sort of affinity between the two groups, holding that the second one has derived from the first by an in situ physical desintegration of coarser fragments from original cryogenic slope deposits. As the parent rocks in the Oesling also for a great deal are composed of clay-sized material, the associated slight increase of clay supports such an explanation.

The transfer of silt and clay through the mantle of loose subsurface material from slope-upward sites towards the actual ground surface at lower levels, however, might have been an additional mechanism, which could have produced the higher silt and clay contents in the second group. The ground-surface layer, being intermittently or perhaps even continuously percolated by subsurface runoff, might be enriched in this way in silt and clay. Neither can eolian supply of silt-sized material as a potential cause of the higher silt abundance in the second group be precluded.

8.4. Thin-section observations

Microscopic study of thin-sectioned undisturbed samples yielded some interesting phenomena which are worth a discussion, in spite of the fact that the sampling nor the optical study was done systematically.

Plate 7.a: Thin-section cut perpendicular upon that presented in Plate 6.c and at a site where the "silt-bearing" layer was thicker. It shows vertical texture changes due to differences in interstitial infill. There is a noticeable increase of matrix towards top and bottom of the thin-section. Height = 12 cm.



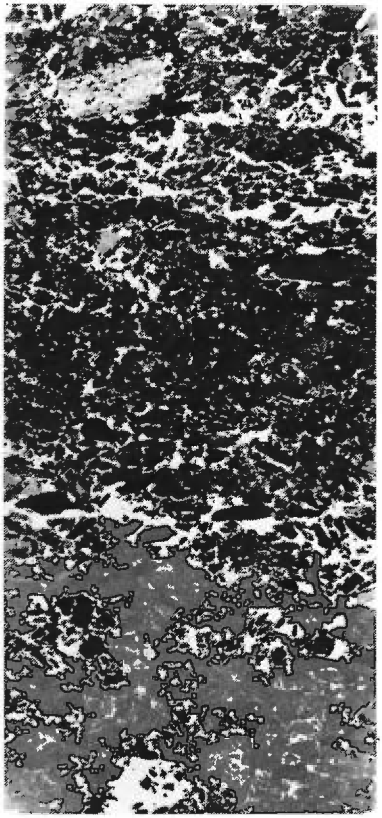


Plate 7.b: A sharp textural change (dashed line), which is evidently only due to an abrupt change in particle size. Height = 13 cm. Depth is about 15 m below surface in the south-facing wall of the Enscherange pit (Plate 4.c).

Plate 7.c: Thin-sectioned upper portion (11-24 cm) of the soil-like, charcoal-containing layer in the Rodershausen excavation (fig. 8). The clasts seem to be slightly more rounded and, although a certain degree of parallelism seems to have been preserved c.q. reproduced, they are more randomly oriented. Under the petrological microscope this becomes in particular clear from a smaller number of clasts cut more or less vertically to their fissility.

Clasts carrying macroscopically visible caps of smaller detrital particles, were carefully collected from open work beds (Plate 6.a). Under the microscope it appears that the flat, coarser cap constituents may be oriented more or less parallel to the upper side of the carrying clast (Plate 8.c and d). This subparallelism seems to get lost in proportion as the sizes of these flat components diminish, or as the distance in the cap towards the upper surface of the carrying clast increases. Equidimensional constituents of fine-sand and silt sizes are mostly found in differently shaped concentrations upon or between the flat, larger components (Plate 9.b). Dominating silty domains inside the caps, may contain a substantial amount of clay, obviously acting as cementing material (Plate 8.a and 9.a). Pure clay concentrations are observable at clast contacts, in internal clast cracks, as partial infill of small voids, and as wall coatings of open spaces in particular near the grain contacts (Plate 8.c and 9.c). They all indicate clay precipitation from evaporating interstitial water.

At least two mechanisms seem to have played a role in the formation of this sort of caps, which show some resemblance with silt caps described by BOCQUIER (1971). First a spalling off of the margins of the supporting clast occurs, following in particular planes of weakness. Such a periodic or continuous action may result in a number "satellite clasts" on top of the parent clast, and makes the general upward decline in size and parallelism of the larger flat, cap constituents explainable. An additional contribution to the cap's framework might happen by "satellites" separated from the under-sides of above situated clasts.

Trapping of fine-sand and silt particles and naturally also of clay, from through-flowing and evaporating waters forms the second mechanism. The trapped clay (Plate 8.c and 9.c) especially promotes the stability of the caps. Both mechanisms may operate together, but it is obvious that the first one is more closely related to freeze-thaw conditions whereas the second will especially be stimulated at those sites where the first one has been active.

Other interesting phenomena are the included and irregularly distributed, less or more extensive layers and beds with a different texture (fig. 6). Viscuous debris flows and other sort of debris movements, are usually considered to be responsible for their formation (WASSON, 1979). The difference in texture between these layers and the adjacent debris, which can be expressed in numbers, sizes, shapes and orien-

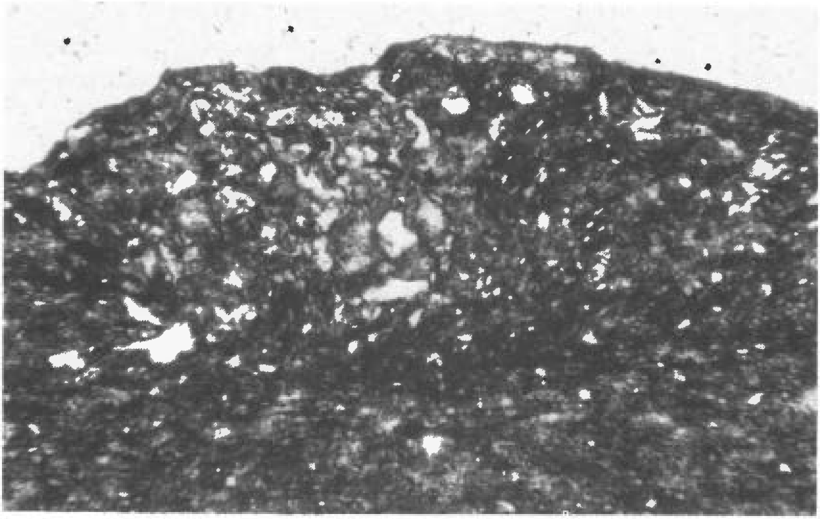


Plate 8.a: Micrograph: Silt cap developed upon a flat rock fragment inside the framework of stratified screes. It shows an intimate mixing of silt-sized clay-lumps and mineral particles. Plane-polarized light. Magnification ca. 175 x.

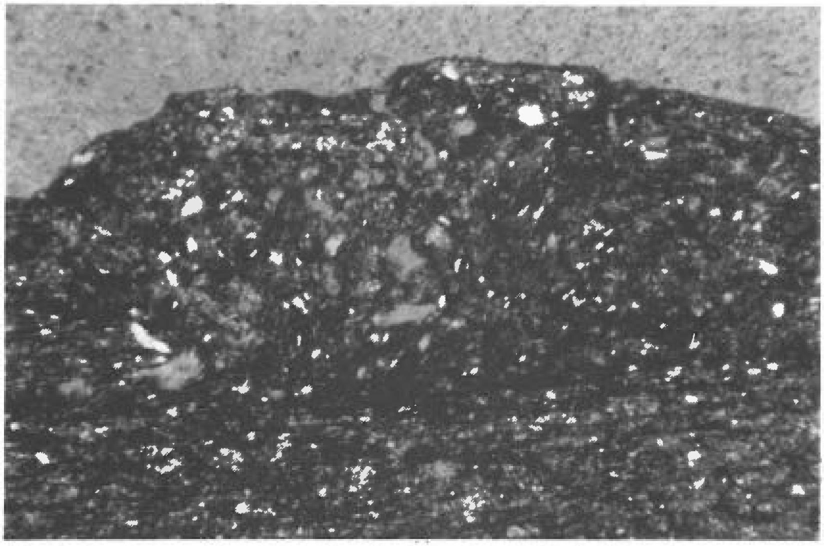


Plate 8.b: Micrograph: Same picture under crossed nicols and with superposition of a gypsum plate. Notice the difference in fabric and also porosity between the left and the right portion of the cap.

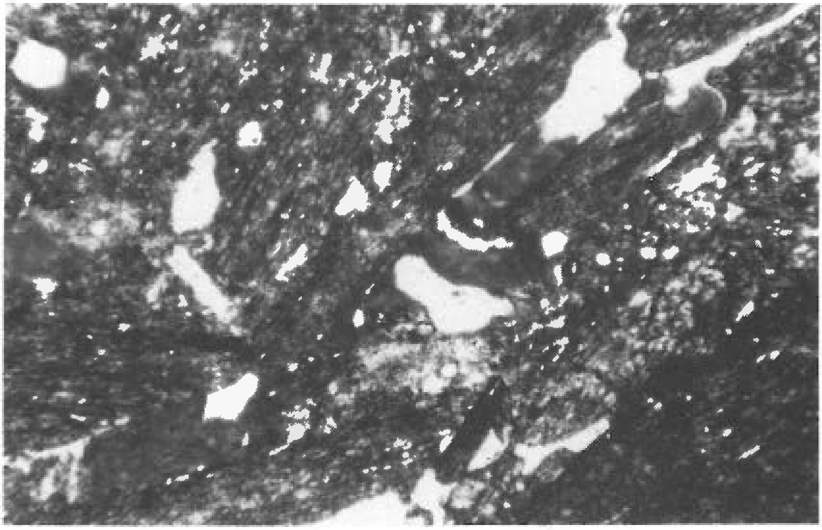


Plate 8.c: Micrograph illustrating isolated clay precipitation in interstices of various shapes and dimensions within a cap. The carrying rock fragment is visible in the lower corner to the right just underneath an irregular mixture of silt and clay. Plane-polarized light. Magnification: ca 175 x.

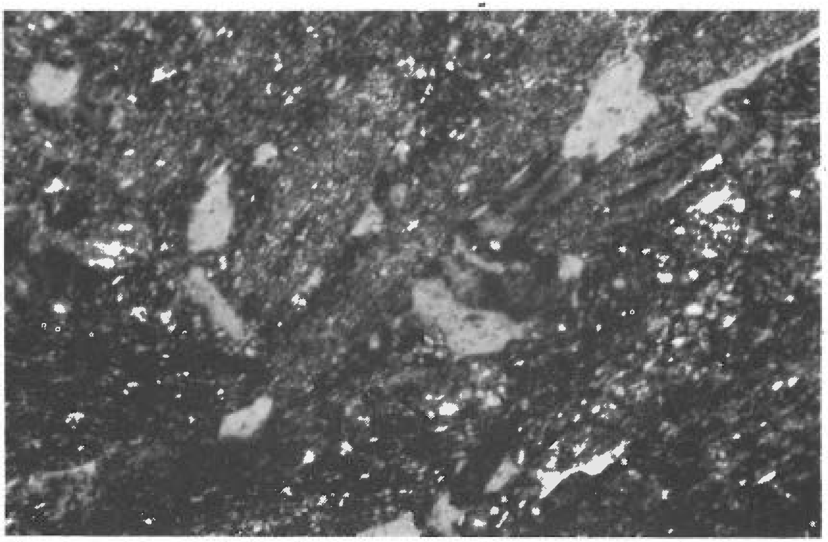


Plate 8.d: Micrograph: The same photograph with crossed nicols and gypsum plate. It shows the similarity in optical orientation of the "parent" and several "satellite" clasts.

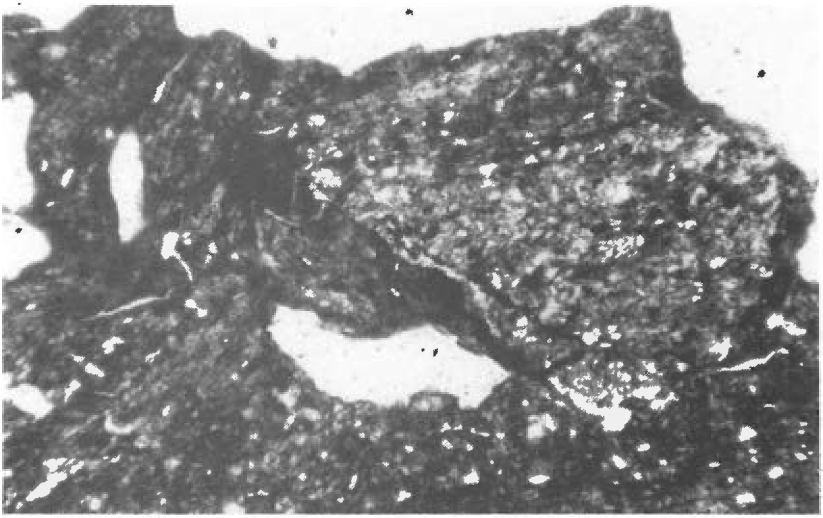


Plate 9.a: This specimen illustrates in particular the role of precipitated clay in cementing the cap constituents. Probably this clay was separated in an earlier phase with another pattern of cap-constituents. Notice that the present pores hardly show clay infill. Plane-polarized light. Magnification: ca. 175 x.

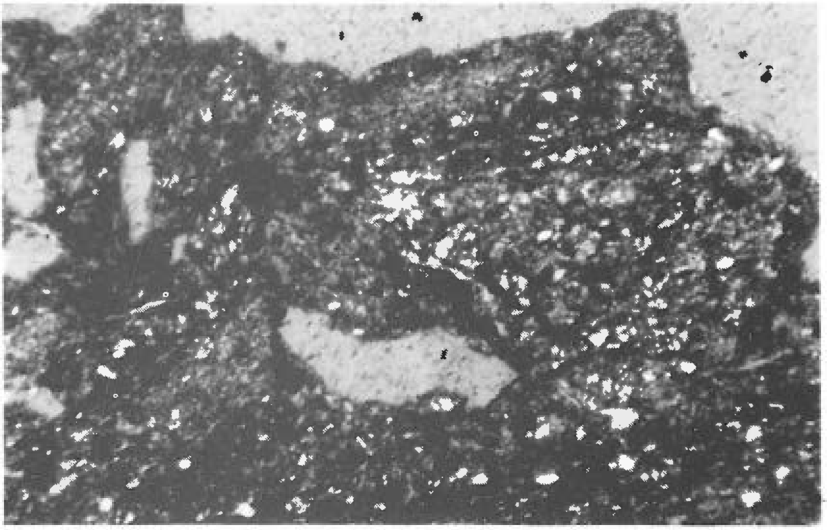


Plate 9.b: Micrograph 9.a under crossed nicols and gypsum showing the dissimilar optical orientation of the coarser cap constitents and the incorporation of silt particles in the cementing clay.

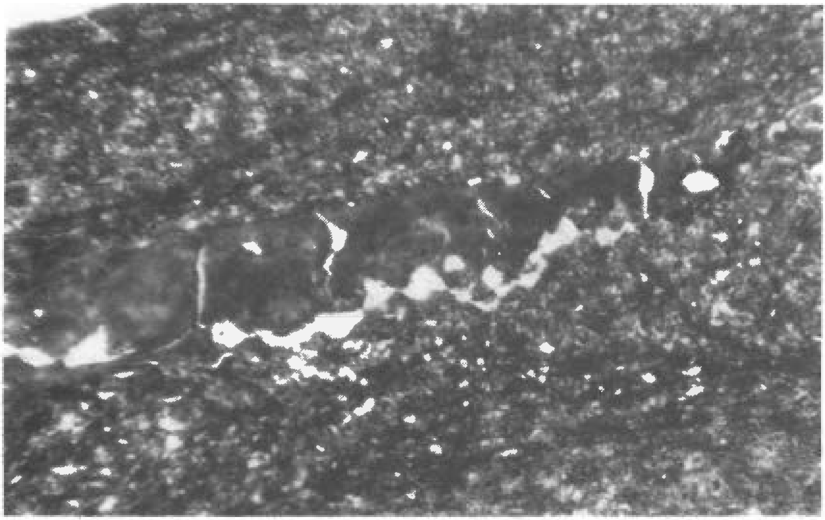


Plate 9.c: Two-phase infill of the space between more or less parallel, flat, rock fragment surfaces. First, an irregular mixture of silt and clay was deposited, and later on the remaining space has been filled up by clay. Plane-polarized light. Magnification: ca. 175 x.

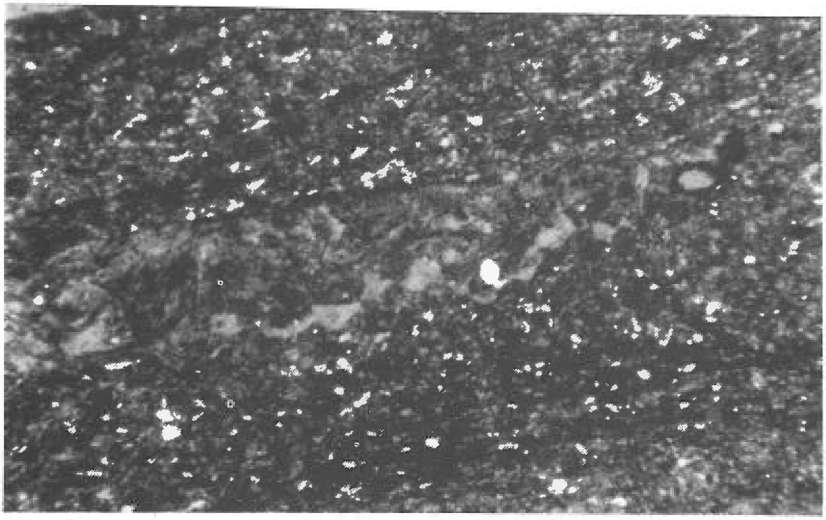


Plate 9.d: Same micrograph with crossed polars and superposition of gypsum. It shows different optical orientations within the pure clay lamina, which might point to precipitation in more phases, or to a subsequent deformation of the clay.

tations of clasts, in clast-matrix ratios etc. is seen as a argument in favour of this explanation. It is based on the assumption that the perceptible texture features represent primary, synsedimentary arrangements of the material.

There are instances in which the features observable in thin sections seem to support this view (Plate 7.b and 8.c). But in other cases (Plate 6.c and 7.a) microscopic observations seem to suggest that the differences in texture may have been caused also by modifications occuring post-depositionally. This statement emerges in particular from the impression that the fabrics of the clasts in texturally different zones, seem to be more or less similar, and from the way in which the interstitial space is filled in (Plates 8 and 9). These micrographs give the suggestion that the matrix formation in certain places of the stratified debris is still in progress, in addition to which primary fabric features may also be changed in some degree (Plate 9.a and b). As far as concerns the groundmass development, sometimes areas are visible with intimate mixtures of silt particles and silt-sized clay aggregates, suggesting a simultaneous accumulation between or upon the coarser framework components (Plate 8.a and 9.c). Other micrographs, however, show evidently incorporation of only clay-sized material (Plate 8.c and 9.c). Occasionally multiple alternations of separate clayey and silty additions to the interstitial infill have been seen.

So, although, e.g. matrix-supported layers are commonly thought to be exclusive products of certain sedimentation processes - and accordingly interpreted - it is questionable whether this is always correct. It might be possible that a set of like textural features results from post-depositional processes too.

Finally, the microscopic observations exhibit in accordance with the field evidence that intergranular porosity may be very high (e.g. Plate 7.b and Plate 8.d and 9.b). Additionally it is revealed that matrix and fracture porosities just as well deserve attention in possible further textural studies (Plate 8.a and b; Plate 6.a).

Especially this property may offer today during storms and periods of high water table ample opportunity for throughflow of water loaded with silt- and clay-sized particles (Plate 7.b). Where present in the subsurface of the modern Oesling catchment areas, grèzes litées beds of this type may highly affect the output on the footslopes and into the stream channels. Changing and uncommon hydrograph curves and unusual amounts of suspended solids in channel waters might be connected with the continuous or discontinuous presence of such slope deposits in the subsurface. They may influence substantially the vertical and lateral hydraulic conductivities in the mantle of loose surface debris, and in this way they are co-controlling the relationships between the events occuring on the slopes and the responding actions and effects in the valleys and stream channels.

CONCLUDING REMARKS

The estimated ages inferred above suggest that the relict slope deposits very probably date from the Weichselian. It can, however, not be precluded that the lower unit in the Rodershausen pit virtually is made up of original Saalian screes material, that in the course of the beginning of the Weichselian (Early Glacial) has been reworked and redeposited. Apparently, environmental conditions suitable for the production and subsequent accumulation of screes material have been prevailing throughout the Weichselian. This does not contradict the findings of BASTIN et GUILLIEN (1971) and GUILLIEN (1973) stating that stratified screes develop under a severe climate during pleniglacial times, nor the experiences of BOARDMAN (1978) who situated ca. 10 m thick grèzes litées accumulations in the Younger Dryas (Late Glacial) and claims them to have been originated under periglacial conditions.

Among the numerous conditions necessary for the formation of stratified screes, the availability of steep rock surfaces exposed to frost-shattering and other mechanisms of rock detrition - in particular at the higher topographic levels in the landscapes - is undoubtedly a very important prerequisite. The small rocky ridges surfacing from the screes in the Eschweiler quarry clearly illustrate that (fig. 5 and 7, Plate 3.a). But as already has been emphasized by WASSON (1979), the range of environments giving rise to stratified screes formation must be much wider than those comprised by periglacial regions. In deserts and semi-deserts screes formation is likewise a frequent phenomenon.

Initial deposition on the slopes has very probably occured by single particle fall and associated grain flows (WASSON, 1979). The formation of clearly perceptible individual layers, beds, lenses or otherwise shaped entities with different textures may be due to subsequent surface wash comprising sheet and rill wash, talus creep, mass wasting, debris flow, etc. connected or otherwise with seasonal influences. To what extent, however, re-arrangements or additions of individual components after the primary or secondary deposition of the stratified screes, may modify or generate the large-scale textural features in sections, remains unsolved for the time being.

All these processes tend to concentrate the screes at the foot of the slopes, where it may be subjected to further transport into the valleys by gullying (fig. 5), lateral stream erosion and other reworking processes. The bottom pavements in many of the modern river channels of the Oesling represent even nowadays the remnants of these Pleistocene debris transports.

The relic accumulations, in particular that one exposed near Enscherange, suggest that at least locally the landscape morphometry must have been thoroughly altered troughout the Weichselian. True, slope upwards of the deposits manifest hill tops are discernable in the present topography (see fig. 2 and 3), but nearby distinct terrain features, which could be held responsible for the production and supply of the scree preserved in steeply sloping accumulations (see Enscherange) are lacking. These terrain forms have been apparently buried by their own waste products, or have been consumed by freeze, thaw and refrigeration processes.

Repeated freezing producing expansion and destroying the rock coherence, may also have been an important agency in shaping the present Oesling valleys. They show generally an anormal width in comparison with their depth, and also in view of the streams employing them (''underfitted streams''). Drastic Pleistocene incision is thought to be the dominant cause, but the recession of the valley side walls has probably highly been promoted by countless freeze-thaw cycles.

It is quite possible that stratified debris beds of different Weichselian ages, thicknesses and textures are still found at several locations in the Oesling subsurface. Where present, they have undoubtedly played a role in the past landscape development. But also today they probably co-affect the generation of runoff processes and thus the erosion of the landscapes (Chapter 9.8, WARD, 1975). Total runoff volumes, shapes of storm and melt-water hydrographs, time lapses between quick and delayed flow (HEWLET and HIBBERT, 1967) etc. may substantially vary as a function of the subsurface properties in the various catchment areas (Chapter 8.11,WARD, 1975). Particularly debris bodies with open work or partially open work fabrics may offer huge storage and conveyance capacities, and their extensions and spatial orientations may influence speed and directons of interflows and groundwater flows.

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