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SOME GEOMORPHOLOGICAL IMPLICATIONS OF THE CRYO-AEOLIAN DEPOSITS IN WESTERN BELGIUM

Résumé

Dans une partie NW de la Belgique (fig. 1) nous étudions l'interaction des dépôts cryo-éoliens et de la géomorphologie. Le relief y est adouci par une couverture de loess et sable éolien (fig. 2).

Sur les loess, il existe des valeurs de pente typiques, qui varient selon la teneur en sable: 5%, 6% ou 7% selon que le loess devient plus pur (fig. 3A). De même, dans les convexités et concavités les valeurs de pente dominantes sont de 2%, 3% ou 4%. Ces valeurs dominantes le sont encore davantage dans les sections rectilignes des pentes (fig. 3B).

Il existe une forme géométrique typique des profils pour les pentes couvertes de loess. Nous représentons ces pentes par leur courbe des valeurs d'inclinaison (fig. 4), courbe bien plus propice quel e profil classique, à la description de ces pentes faibles. Ces courbes sont définies au moyen de fonctions y' = f(x).

Sur les replats, la couverture cryo-éolienne manque souvent lorsque le substrat est d'argile. Nous expliquons ce phénomène par la grande sensibilité de l'argile aux mouvements de masse, sous climat périglaciaire: ainsi, toute végétation étant détruite, il n'y a pas d'obstacles pour capter les sédiments cryo-éoliens.

Dans la zone de transition entre sables éoliens et loess, la limite entre les diverses granulométries est souvent liée au contexte géomorphologique: notamment au pied de versants face au W—NW—N (fig. 5) ou dans un talweg orienté SW—NE à W—E. Ceci est dû au moyen de transport différent du sable (par saltation) et du loess (en suspension). La position de ces différentes granulométries permet de conclure qu'à la fin du Wurm les vents y soufflaient probablement surtout du W—SW.

The relief in the northern and central part of Belgium is covered with periglacial aeolian deposits (cryo-aeolian), mainly from Wurm age. In the western part of Belgium, namely between the rivers Lys, Scheldt and Dender (fig. 1), we investigated the interaction between these sediments and the geomorphology. We especially paid attention to the distribution of the cryo-aeolian cover in relation to the geomorphology, to shape and steepness of their slopes, and also in relation to the substratum geology.

In this country the cryo-aeolian sediments vary from coversands in the north towards pure loess southwards. The way of transition between these different granulometries is another aim of our study.

THE GEOMORPHOLOGICAL CHARACTERISTICS OF THE INVESTIGATED REGION

The relief belongs to a plateau level which elevates stepwise from 50 m into the north towards 120 m into the south. A highly dense valley system (over 5 km pro km^2) dissects this relief in a lot of valleys, slopes and elongated hills (Vanmaercke-Gottigny, 1969). Upon the plateau level an east—west row of isolated hilltops rises 150 m high. The valley erosion, from Pleistocene age, happened in Eocene

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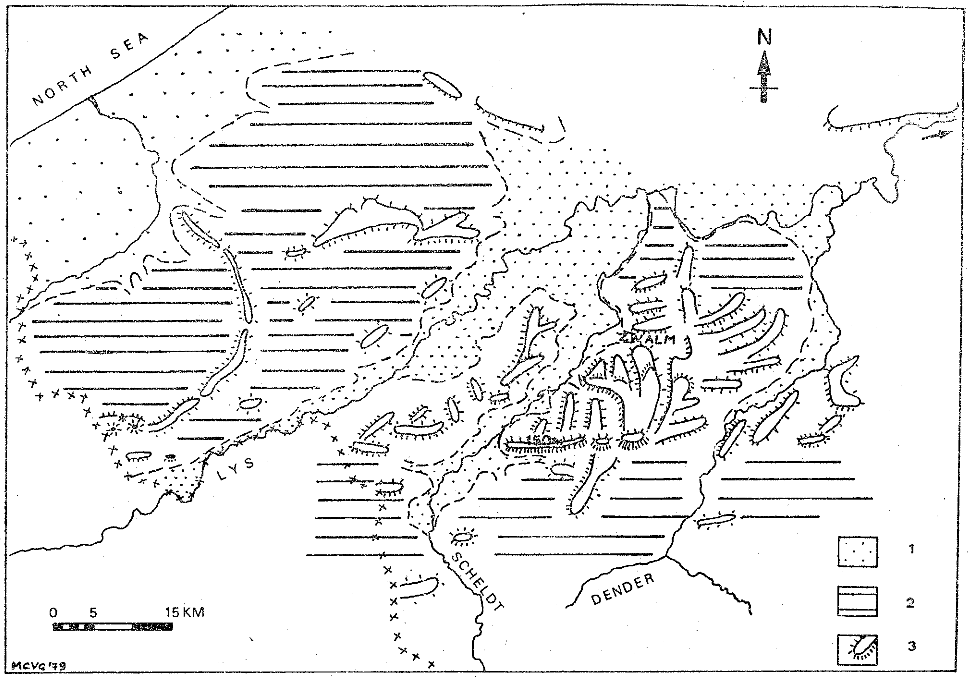

Fig. 1. Geomorphological outline of the investigated region between the rivers Lys, Scheldt and Dender

1. fluvio-aeolian and aeolian filled depressions; 2. planated areas; 3. hills (higher than 40 m)

subhorizontal layers which consist of a quick alternation of clay, sand and mixtures of both. The valleys are 10 m to 70 m deep, and slopes are mostly between 2% and 15% steep.

An important part of the relief is smoothened by Wurm cryo-aeolian cover deposits. Our investigations reveal a rather continuous thick cover on some flat levels and on the slopes orientated to the SE-E—NE-N (fig. 2), whereas the otherwise orientated slopes only carry a thin and discontinuous cover or nothing at all (Vanmaercke-Gottigny, 1967). These data however agree with the well-known characteristics of the cryo-aeolian cover in a large part of Europe. As this cover is so important in the relief, we wanted to examine its influence on the morphometrical and geometrical characteristics of the slopes.

THE MORPHOMETRY OF LOESS SLOPES

The region between the rivers Scheldt and Dender, the most hilly, belongs to the loess belt; so we made here a detailed morphometric analysis of the loess-covered slopes. In fact we here have the transition area between sandy loess (over 50% coarser than 44 mu) and loess (10 to 20% coarser than 44 mu) (granulometrical analysis, Vanmaercke-Gottigny, 1967). We took into consideration only those slopes which carry more than one meter loess.

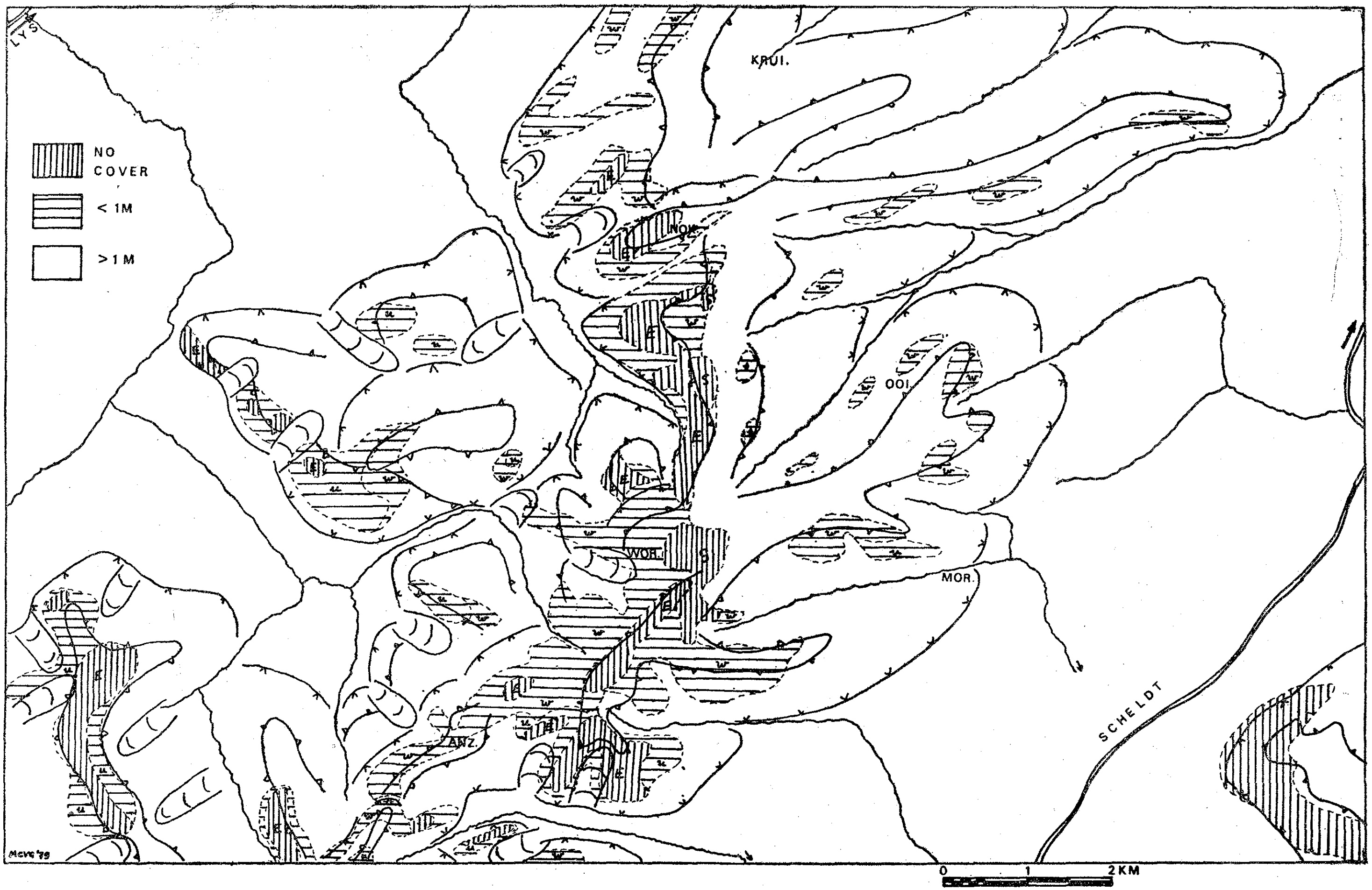

Fig. 2. Map of the cryo-aeolian cover in a part of the Lys-Scheldt interfluve, drawn on a schematical geomorphological map

Lithology of the uncovered Eocene substratum: E – clay, up to the surface; S – sand up to the surface; u – clay under less than 1 m cover; w – sandy clay under *idem*; s – sand under *idem*

This analysis is based on slope profiles measured on the field, with a standard measurement interval of 10 m. According to the height of the plateau level, we divided the area into four subareas:

I. north of the lower-Zwalm river, with heights reaching to 60 m;
II. more southwards where the plateaus are 60—80 m high;
III. south of a sudden stepwise elevation up to 100—120 m;
IV. an area south of the mentionned E—W row of hills of 150 m high.

On each of these subareas we considered a homogeneous distribution of slope profiles, 197 in total, with an average length of 180 m (18 measurements). Because of the flatness of this relief, we measured the slopes in percents rather than in degrees, since most of the values vary between 2% and 7% (this should be 1° and 4°!).

Statistically, we asked for the dominant loess slope values in each subarea. The histogram of these data (fig. 3A) shows the following results:

— loess-covered slopes are rarely steeper than 7%;

— in each subarea there are two typical, dominant slope values (fig. 3A and tab. I);

— the steepest dominant slope value is respectively 5% (subarea I), 6% (II and III), 7% (IV), due to a decreasing sand content;

— the more gently dominant slope value is 2 to 3% (I and II) and 3 to 4% (III and IV); due to the same reason.

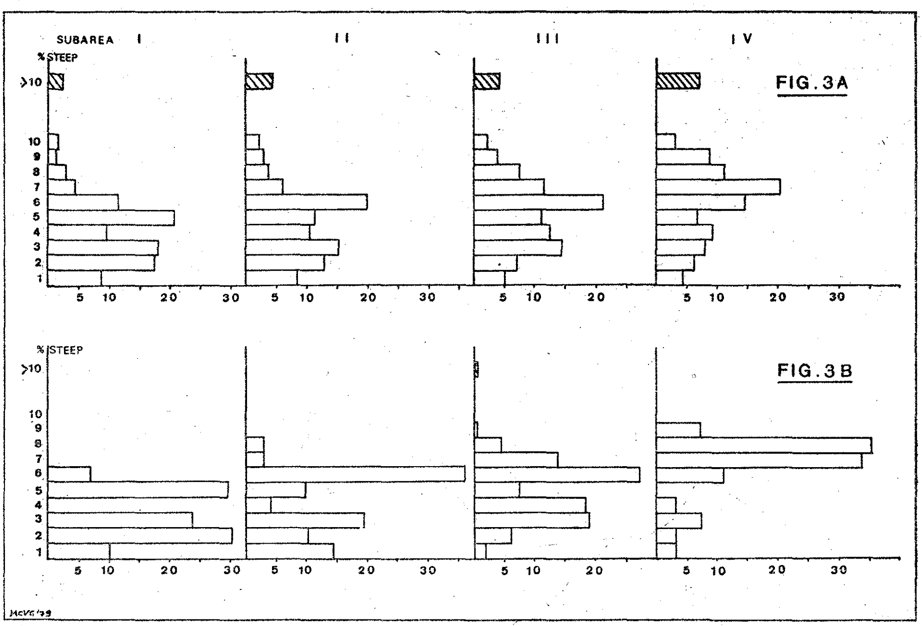

Fig. 3. Histograms of slope values on loess-covered slopes

A — histogram of all the slope values of 197 profiles; B — histogram of the slope values of only the rectilinear segments of these profiles; In ordonnate: the slope values measured in percents. On the abscissa: number of measured values in percent

— if a loess-covered slope has a segment steeper than the steepest dominant value, we found out that such a segment carries a thin loess cover (less than 2 m), or is recently denudated by lateral erosion.

Table I

Subarea	Number of profiles	Number of measurements	Dominant steepnesses			
			Steeper slope value		More gently value	
			dominant slope value	percentage number	dominant slope value	percentage number
I	27	465	5%	22/100	2–3%	35/100
II	54	1065	6%	20/100	2–3%	29/100
III	78	1574	6%	22/100	3–4%	27/100
IV	38	519	6–7%	36/100	3–4%	17/100

Besides, those dominant values are still more dominant when we consider only the rectilinear slope segments. With rectilinear segments we mean, in this case, segments whose slope value is constant (±0,5%) over at least four measurements, this is 40 m or nearly a quarter of the length of an average slope profile in this area. Thus the dominant values are frequently found in rectilinear slope segments. The histogram (fig. 3B) shows the percentual distribution of the slope values only in such rectilinear segments: the maxima are more accentuated. When we consider the ratio between all the measurements of a typical value and those found in rectilinear segments, we obtain:

— area I: the 5% measurements are found in 38 percent of the cases in rectilinear segments;

— area II: the 6% measurements in 47 percent of the cases;

— area III: the 6% measurements in 39 percent of the cases;

— area IV: the 7% measurements in 38 percent of the cases.

The same conclusion can be observed for the more gently dominant slope values.

The more gently dominant slope values are found in the basal concavities as well as in the summital convexities, in rectilinear segments if the slope is long enough. Nevertheless, the same values also constitute the slopes of positive loess accumulation bodies, as they exist either in some large valleys or on plateaus.

THE GEOMETRICAL SHAPE OF LOESS SLOPES

At present the point is to know the geometrical form of the loess-covered slopes, investigating if some typical profile forms exist, corresponding to the found dominant slope values. We analysed well-chosen slope profiles, the same 197 as those used for the former statistical analysis. Indeed, as the downward sence of a slope is the most important for erosion and transportation, we took into consideration only the geometrical shape of vertical sections in the relief.

A slope profile can be drawn into carthesian axes, where [y = height] and [x = horizontal distances]. So the slope profile, in its entirety or in segments, corresponds to one or more functions of [x, y]. But it would not be easy to establish (without a computer), nor to read, such a curves based on field measurements, and one would get a tremendous great number of different functions (RUHE, 1950; PAEPE, 1968; ONGLEY, 1970, e.a.).

Besides, in such smooth relief, slope profiles are not so clear to read, unless when we apply an important vertical exaggeration, as we did in fig. 4A. In that case, however, we do not have an exact view of the shape of the slope. For that reason, we constructed slope value curves (fig. 4) which show the succession of the slope values (noticed on the y-axis), and this to begin from the base of the profile. SAVIGEAR (1956), DE BETHUNE and MAMMERICKX (1960), YOUNG (1972) and some others used analogous graphics; we however, use these curves as mathematical curves drawn by means of known points: each point is a measured slope interval of 10 m. So these curves can be written as functions of [x = intervals, y = slope values].

Approximately, the slope value curve can be considered as the first derivated curve of the slope profile which is, in carthesian coordinates, a cumulative height curve (y = height). Since in the slope value curve we have [y = steepness in %], the vertical axis gives us for each interval [d.y/d.x] (i.e. meters denivellation pro 100 m distance). So the function of the slope value curve can be written as y′.

The different slope segments each have their own function. In this way, straight slope segments (S) appear on the slope value curve as horizontal segments (fig. 4). While in a slope profile they correspond to the function [$y = ax+b$], in the slope value curve they are written, much more plainly, as [$y' = a$], where a is the slope value.

Concave slope segments (CC) are represented by increasing parts of the slope value curve. Such segments can response to different kinds of functions, characterising the type of curvature of the concavities. For instance:

— straight increasing parts [$y' = ax+b$] when in reality the relief concavity is a parabola [$y = ax^2+bx+c$];

— upward concave parts of the curve if, for example, the real profile corresponds to a polynomial function of x (with the degree greater than 2, and $a > 0$, $b > 0$), or to an exponential function [$y = a^x$] (whereby $x > 0$, $a > 1$);

— upward convex parts when the concavity is, for instance, a polynomial of the third degree (with $b > -2ax$).

It is clear that all these y′ curves are more simple than the y functions, both to read and to establish.

Convex slope sections (CV) are in the same way represented by decreasing segments of the y′ curve (fig. 4).

After treatment of the 197 profiles by means of this graphical-mathematical method, we could come to some typical functions for loess slopes.

A loess-covered slope has a typical slope value curve, which is frequently CC-CV

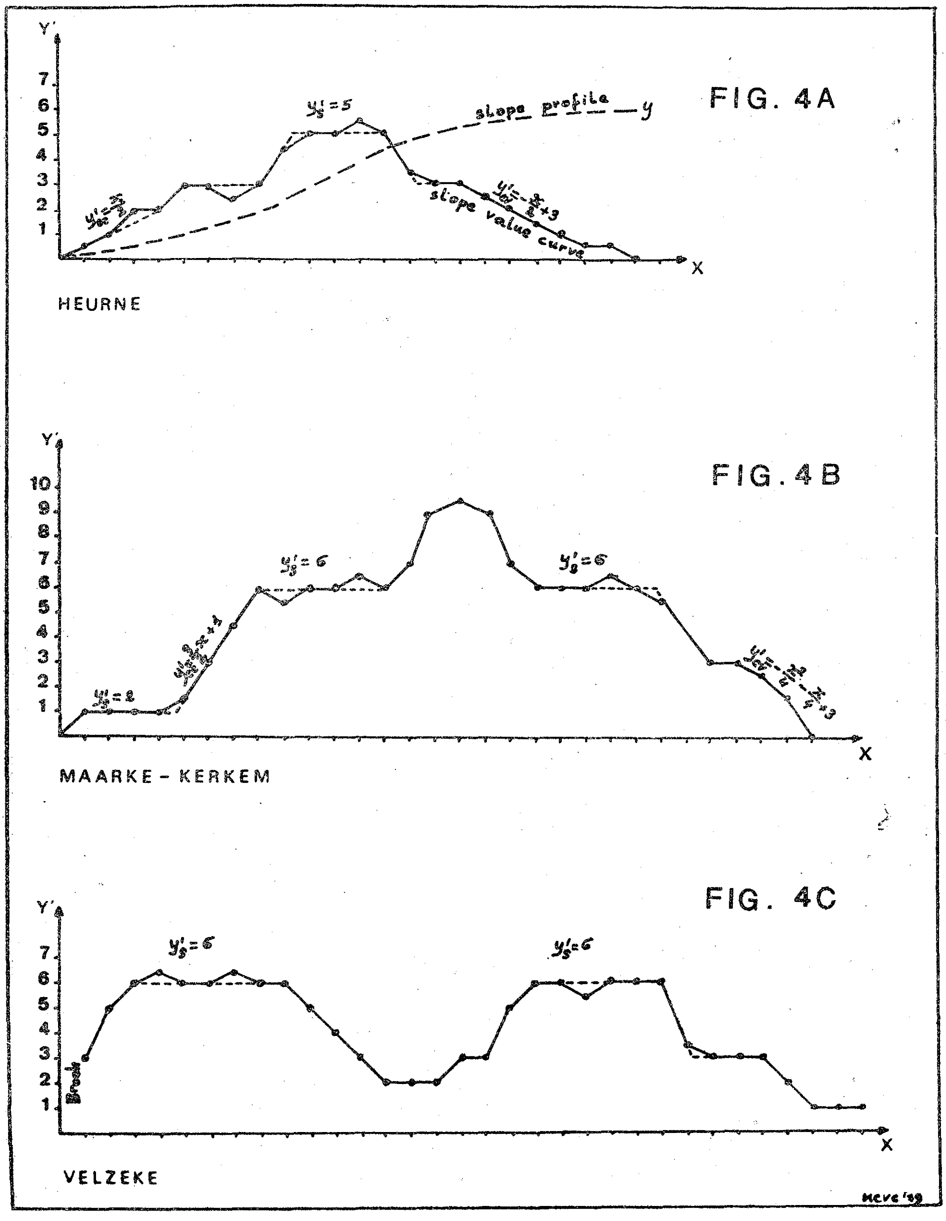

Fig. 4. Slope value curves of loess-covered profiles

Y-axis: the measured slope values. On the abscissa: the succession of measured intervals. The slope profile in fig. 4 A is surimposed, with a height exaggeration

or CC-S-CV; this means that the y′ curve has one maximum: a point or a horizontal line (fig. 4A: "Heurne" in subarea I). Analysing such curves in their different sections, we often obtain:

– for the concavities:

$y'_{cc} = ax+b$ (a varying from 1/2 to 2)

$y'_{cc1} = ax+b$ $y'_{cc2} = a = 2\%$ or 3% or 4% according to the subareas. Nearly never we get $[y' = ax^2+bx+c]$ for loess concavities;

— for straith profile segments:

$y' = a = 5\%$ (I), $= 6\%$ (II and III), $= 7\%$ (IV);

— for the convexities:

$y'_{cv} = -ax+b$ (a varying from 1/2 to 2)

$y'_{cv1} = -ax+b$ $y'_{cv2} = 2\%$ $y'_{cv3} = 1\%$

Scarcely: $[y'_{cv} = -ax^2-bx+c]$ when the convexity is rather abrupt. The typical loess curve thus is gaussian-like with a well-determined maximum and typical inclinations.

However, loess-covered slopes can be more complex. In fact, there are two kinds of complications occurring in our loess slopes:

— the elementary y' curve is interrupted by a slope increasing, so that a peak elevates above the gaussian-like curve. This peak often reaches to 8—12% steepness (fig. 4B: "Maarke-Kerkem" in subarea III),

— the curve is interrupted by a slope flattening, this means a depression in the gaussian-like curve (fig. 4C: "Velzeke" in subarea II).

Further investigations taught us that both these phenomena are normally due to litho-structural influences of the substratum under the loess cover which in these cases is thinner. In our region the slope increasing occurs on sand layers, while slope flattening happens on clayey substratum.

Note. This slope analysis can be extended to a third curve, where the differences of slope values between two successive measurements are put on the ordonnate and the succession of these differences on the abscissae. In a way, such a curve is a second derivation y'' of the slope profile. This curve would show us the repartition and intensity of convexities (under the abscissa), concavities (above the abscissa) and straight segments (on the abscissa). Also in this manner one can investigate typical loess curves.

THE CRYO-AEOLIAN COVER ON PLATEAU SURFACES

Mapping the cryo-aeolian cover between Lys, Scheldt and Dender, we noticed that a lot of plateau surfaces bear several metres of these sediments, whereas some others carry only a few decimeters or nothing at all, although they lie near each other. We found a correlation between the presence of cover and the lithology of the substratum: if a flat level is eroded in clay, there is nearly no cryo-aeolian cover (fig. 2, e.g. SW edge); on the other hand, if the level lies on more or less sandy layers, the cover is usually at least 1 m thick.

Since it appears that the lithology is determinant, being the only variable, we have to find a reason for sediment-trapping on sandy surfaces, which did not exist on clay surfaces. Nowhere in literature we could read analogous investigations, whilst we heard from some colleagues that the same phenomenon occurs in several regions. Should the vegetation be the trapping elements, as it seems to be logical, then we can agree that a daily or seasonaly freeze-and-thaw destructs vegetation on clay much more than on sandy soils. Indeed, clay has a greater capilar water retention capacity, up to the surface, and thus also more ice segregation. Every temperature elevation then can be followed by mass movements, destructing any sprouting vegetation.

THE INFLUENCE OF THE PRE-EXISTING RELIEF ON THE GRANULOMETRY OF CRYO-AEOLIAN DEPOSITS

If the cryo-aeolian deposits influenced the shape of the relief, also the pre-existing morphology had an influence on their way of deposition, determining their granulometrical properties in the transitional area between sandy and loessy sediments. In a small part of such an area, a part of the Lys-Scheldt interfluve, we put the granulometrical data of the superficial cryo-aeolian layers on a schematic geomorphological map (fig. 5). We got these data from the Pedological Map of Belgium, and from our field investigations.

The transition between coversands and loesses is abrupt, since sandy loess deposition is nearly absent. This phenomenon very often occurs in the transitional areas between coversand and loess. In many places this boundary corresponds to an elevation in the relief, as can be seen in the southern-central part and in the NE edge of map 5. Nevertheless, elsewhere the same boundary occurs in the middle of a slope or, more exceptionally, on a flat level. Between Scheldt and Dender, however, this boundary is situated on a rather large, WSW—ENE orientated valley floor (fig. 1: river "Zwalm").

The sudden transition between sand and loess can, in our opinion, be interpreted by the different way of deposition of these two sediments: the first one by saltation, the second one by suspension. It then is logical that a relief elevation can stop more or less the saltation. Investigation of the deeper aeolian deposits shows that the considered boundary varied, through time, to a certain amount around luff slopes of a relief elevation. On the contrary, on a valley floor the same boundary stayed much more constant: this wet area stopped a sand saltation efficiently, whereas loess suspension of course passed over without any notion of the wet area.

The limit between coarse (Z) and fine (S) sands on the one hand, and between light (L) and pure (A) loess on the other hand, also often corresponds to luff side slopes (e.g. fig. 5; 2 km SE of Waregem), but they never coincide with wet valley floors. This is logical, since for both the granulometries the same process transported either sand, in saltation, or loess, in suspension; the only difference between Z and S, and between L and A transportation, must have been the height of transportation.

The direction of the sand and loess bearing winds at the end of the Wurm can be read from map 5. As is already known, the asymmetry of the cryo-aeolian cover (fig. 2) is partially due to the slope orientation facing the dominant periglacial winds. However, the granulometrical distribution of these deposits can inform us still

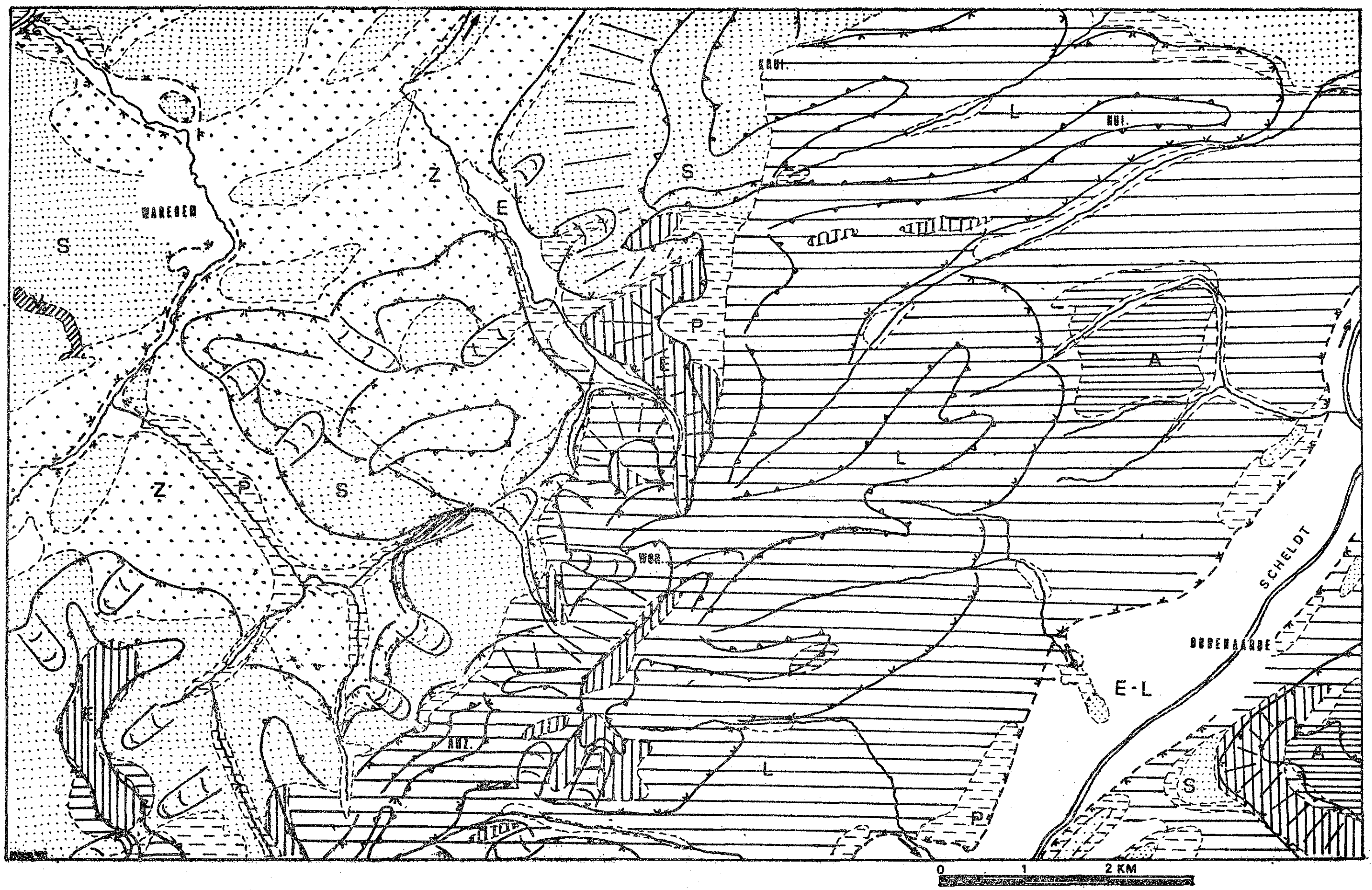

Fig. 5. Granulometry of the superficial cryo-aeolian deposits in a part of the Lys-Scheldt interfluve (drawn on a schematical geomorphological map)

Z – coarse sand; S – fine sand; P – sandy loess; L – light loess; A – pure loess; E – (hatched) Tertiary clay; E and E-L – alluvial clay and silty clay; V – peat better about these wind directions. We can attribute the uppermost deposits to the epi-Wurm, although some are recognised as probably tardiglacial, namely along the main rivers.

The progression from coarse to fine sand, and further to light and pure loess, goes from the NW to the SE, and this even in the whole of Belgium. A detailed analysis of for instance map 5, brings us to some interesting conclusion: at the same latitude, the Scheldt valley is covered with loess there where we see that the valley is protected behind the Lys-Scheldt interfluve, whereas the Lys valley is covered with sand. Therefore these epi-Wurm winds must have come more or less from the West. What is more, near Waregem (map 5), some flat WSW—ENE ridges of coarse sand exist in the fine sand belt. Analogous ridges appear also in other regions of northern Belgium, but till today nobody knows if they are transversal rather than longitudinal. In the first case the wind ought to come from the NNW, in the latter from the WSW. In our opinion the first possibility is contradictory to the loess-covered Scheldt valley just near the sand-covered Lys valley.

CONCLUSIONS

1. Statistically, we established that there is a typical maximal loess slope value, often occurring in rectilinear segments, according to the granulometry of the loess. This value goes from 5 % to 7 % for sandy loess to pure loess.

2. In the same way, we found out that in loess-covered concavities and convexities the slope values 2 % to 4 % are dominant, and appear also frequently in rectilinear slope segments.

3. The loess-covered slope has a typical geometrical shape, which can at best be expressed by its slope value curve. This gaussian-like curve can be analysed in functions $[y' = f(x)]$. Complications of this elementary curve are mostly due to litho-structural influences of the substratum.

4. Plateau surfaces on clay substratum are often without cryo-aeolian cover, whereas sandy plateaus are covered. We attribute this to the high mass movement capacity of clay in periglacial conditions, destructing even a scarse vegetation, so that there were no trapping elements for cryo-aeolian deposition.

5. The relief influenced the granulometrical distribution of loess and coversand in their transitional area. This was due to the different way of deposition of the sand (by saltation) and the loess (suspension).

6. There are some indications that the sand and loess bearing winds of the Wurm came more or less from the West, but that at the end of the Wurm they came from the W—SW.

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