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THE STRATIGRAPHY AND PALAEOBOTANY OF THE LATE PLEISTOCENE IN BELGIUM

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THE STRATIGRAPHY AND PALAEOBOTANY OF THE LATE PLEISTOCENE IN BELGIUM

by R. PAEPE (*) and R. VANHOORNE (**)

SAMENVATTING. — De stratigrafie van de Boven-Pleistocene afzettingen in België sluit rechtstreeks aan bij deze van het Noord-Europese ruim. Deze bewering is gesteund op het voorkomen in het noordwesten van België van fluvio-marine Eem afzettingen met Tapes senescens *(die de meest zuidelijk gekende uitbreiding vormen van de « Senescens Sande ») en de rechtstreekse laterale correlatie van de interglaciale* Rocourt bodem *met deze marine formaties. Elders werden aan afzettingen, aangeduid als* « Veen en grind », *eveneens een Eem ouderdom toegekend op grond van palynologische bevindingen.*

De afzettingen behorende tot de Laatste Glaciatie periode of Weichsel worden in de volgende litho-stratigrafische eenheden onderverdeeld : zand en grind, leem en grof zand, (venige) leem afzettingen *gezamenlijk het Pleniglaciaal A (koud-vochtige sedimentatie omstandigheden) opbouwend;* kris-kras gelaagde zanden, dekzand en dekleem 1 of 2, *gezamenlijk het Pleniglaciaal B (koud-droge sedimentatie omstandigheden) opbouwend;* laat dekzand 1 of 2 *behorend tot het Laat-Glaciaal.*

Merkwaardige periglaciale horizonten vormen : keienvloer 1 met kleine vorstscheuren *aan de bovengrens van de* leem en grof zand *afzetting;* keienvloer 2 met fijne vorstscheuren *aan de bovengrens van de* (venige) leem afzettingen *en* keienvloer 3 met grote vorstscheuren *aan de bovengrens van de* dekzand *of* dekleem 1 *afzettingen.*

Merkwaardige bodem-vegetatie horizonten treden op : op het einde van het Eem, de Rocourt bodem; *tijdens de afzetting van het* leem en grof zand, *de* Warneton bodem *en op het einde van het Pleniglaciaal A, het* cryoturbaat bodem horizont *(Kesselt-Zelzate - Paudorf horizont); verder een* Stabroek bodem *bij de aanvang van het Laat-Glaciaal.*

Hieruit vloeit voort dat de Weichselperiode door een bi-cyclische sedimentatie wordt gekenmerkt : eensdeels de fase van het Pleniglaciaal A, gekenmerkt door koud-vochtige milieu omstandigheden met dominerend solifluctie processen en anderdeels de fase van het Pleniglaciaal B — Laat-Glaciaal, gekenmerkt door koud-droge milieu omstandigheden met overheersend eolische sedimentatie. Beide cycli worden verder gekenmerkt door het optreden van een extreem koude (deflatie) fase respectievelijk de keienvloer 1 met kleine vorstscheuren *en de* keienvloer 3 met grote vorstscheuren.

RÉSUMÉ. — La stratigraphie des dépôts appartenant au Pleistocène supérieur de Belgique se base — tout comme c'est souvent le cas dans le nord de l'Europe — sur la présence dans le nord-ouest de la Belgique de formations fluviomarines d'âge eemien. Ces dernières sont caractérisées par la présence de Tapes senescens var. eemiensis *(« Senescens Sande »). Leur passage latéral au* sol de Rocourt *a été observé. Ailleurs, les dépôts appelés* « Tourbe et gravier » *sont indiqués comme eemiens à la suite de leurs caractéristiques floristiques.*

Dans les dépôts appartenant à la dernière Glaciation ou Weichsel, les unités litho-stratigraphiques suivantes ont été distinguées : sable et gravier, limon et sable grossier, formations limono-tourbeuses *formant le Pléniglaciaire A (conditions de sédimentation froid-humide);* sables entrecroisés, sable ou limon de couverture 1 ou 2, *formant le Pléniglaciaire B (conditions de sédimentation froid-sec) et finalement* sable de couverture récent 1 ou 2 *datant du Tardiglaciaire.*

Il existe plusieurs horizons périglaciaires importants : cailloutis 1 à petites fentes de gel *se situant à la limite supérieure du dépôt* limon et sable grossier; cailloutis 2 à fines fentes de gel *à la limite supérieure des* formations limono-tourbeuses *et* cailloutis 3 à grandes fentes de gel *à la limite supérieure des* sables *ou* limons de couverture 1.

Il existe aussi des horizons pédologiques, caractéristiques : le sol de Rocourt *datant de la fin de l'Eemien; le* sol de Warneton *datant de la période de sédimentation du* limon et sable grossier; *l'*horizon pédologique cryoturbé *(Kesselt - Zelzate - Paudorf), datant de la fin du Pléniglaciaire A; le* sol de Stabroek *datant du début du Tardiglaciaire.*

Nous sommes arrivés à la conclusion que la période du Weichsel est caractérisée par une sédimentation bicyclique : d'une part le Pléniglaciaire A caractérisé par des conditions de milieu froid-humide avec dominance de processus de solifluction et d'autre part l'ensemble Pléniglaciaire B-Tardiglaciaire caractérisé par des conditions de milieu froid-sec avec dominance de sédimentation éolienne. Les deux cycles sont en outre divisés par une période d'extrême froid (déflation) résultant respectivement dans l'établissement du cailloutis 1 à petites fentes de gel *et du* cailloutis 3 à grandes fentes de gel.

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ABSTRACT. — The Late Pleistocene stratigraphy in Belgium is based on the presence in the Northwestern part of the country of fluvio-marine, Eemian deposits characterized by the presence of Tapes senescens, *known in Northern Europe as « Senescens Sande ». Lateral transition between these deposits and the* Rocourt soil *was observed. Elsewhere, deposits referred to as* « Peat and Gravels » *showed also to be Eemian in age on basis of their floristical characteristics.*

The deposits of the Last Glaciation or Weichsel can be subdivided in the following litho-stratigraphical units: sands and gravels, loams and coarse sands, peaty loam formations *building up jointly the Pleniglacial A (cold-humid sedimentation conditions);* cross bedded sands, coversand or coverloam 1 or 2 *building up jointly the Pleniglacial B (cold-dry sedimentation conditions) and finally* late coversand 1 or 2 *representing the Late Glacial.*

There exist several important periglacial horizons: desert pavement 1 with small frost wedge row *at the upper limit of the* loams and coarse sands; desert pavement 2 with fine frost wedge row *at the upper limit of the* peaty loam formations *and* desert pavement 3 with large frost wedge row *at the upper limit of the* coversand *or* coverloam 1 *deposits.*

Also important pedo-vegetational horizons occur: at the end of the Eem, the Rocourt soil; *during deposition of the* loams and coarse sands, *the* Warneton soil; *at the end of the Pleniglacial A, the* cryoturbated soil horizon *(Kesselt - Zelzate - Paudorf horizon) and the* Stabroek soil *at the beginning of the Late Glacial.*

Finally we come to the conclusion that the Weichselian period is characterized by a bi-cyclic sedimentation: on the one side the Pleniglacial A dominated by cold-humid environmental conditions with preference for solifluction sedimentation processes and on the other hand the joint Pleniglacial B-Late Glacial dominated by cold-dry environmental conditions with preference for eolian sedimentation activity. Both cycles are furthermore divided into two parts by a period of extreme cold (deflation) causing respectively the establishment of desert pavement 1 with small frost wedge row *and* desert pavement 3 with large frost wedge row.

GENERAL STATEMENTS

The increasing knowledge of field-data about the Late-Pleistocene stratigraphy in widely separated areas from Central and Northwestern Europe, supports strongly, as previously advocated especially by J. BÜDEL, J. FINK and T. VAN DER HAMMEN, the tendency for leaving the path of SOERGEL's tripartional and chronological subdivision of the Last Glaciation into a Würm I, Würm II and Würm III phase. J. FINK (1961) and J. BÜDEL (1950) have clearly described the misconceptions about this division and how they found their way into literature. Both pleaded in favour of a stratigraphical system based on field evidence, especially when concerned with periglacial deposits. Rather than applying theorethical concepts, rock sequences are to be derived from field geological data. To illustrate the confusion resulting from the application of purely time-stratigraphical units, J. FINK (1965) drew the attention to the fact that a given moment seven different definitions of the Würm I appeared to exist at a meeting of the INQUA Loess Sub-Commission.

In Belgium too, the question whether a tripartition or a bipartition should be attributed to the up to now so-called Würm periglacial deposits, lasted for several years. The problem hinges mainly on the boundary between the Eem and Würm periods and to some extent between the Würm subdivisions themselves. These controversies of course, did not depend only on the mode of approach but was closely connected with the area of investigation that was dealt with. The descriptions by R. TAVERNIER (1954) yielded from the loess area, permit perfect identification in the field. Later, however, this system is found to be unadequate while making an attempt to include and to interpret observations yielded from the coversand and sandloam regions (R. TAVERNIER and J. DE HEINZELIN; 1957). It is obvious that the descriptions from the latter authors compile rock formations which had undergone different environmental processes. The more over, their descriptions lack reference levels which are indispensable for systematic field investigation.

F. GULLENTOPS (1954) based his bipartitional classification of the Würm on observations mainly obtained from the loam region. His subdivision is established on well defined palaeopedological grounds and thanks to his profile drawings the morpho-stratigraphical horizons are undubiously reproduced.

R. PAEPE (1963-1965), working in the Southwestern part of the Flanders in Belgium and in Northern France recognized for his tripartitional interpretation of the last glaciation, the constancy of palaeosoils, cryoturbation levels, frost wedge rows and desert pavements in the litho-stratigraphical sequence. At that time, he did not always make a sharp distinction between the levels representing major and minor climatical events. Later, stress was laid on the world-wide climatical-stratigraphical importance of some of the periglacial phenomena (R. PAEPE, 1966).

It is our conviction now that very seldom a normal (complete) profile of the Late Pleistocene sequence is found in the field. Parts may be lacking and also the sedimentation pattern can greatly differ. But, we do believe that when the morpho-stratigraphical resemblance between two profiles is obvious, one should not hesitate to conclude as to its analogous climatical-geological evolution. We will see that within the Belgian investigation area neighbouring profiles may differ considerably whereas other profiles may show an astonishing resemblance with sites far away. Profiles yielded from the coversand region tally completely with sections in the heart of the Netherlands and profiles from the loess area with the type localities of Austria (R. PAEPE, 1966). We agree although fully with the statement put forward in a combined paper by VAN DER HAMMEN, MAARLEVELD, VOGEL and ZAGWIJN (1967), that intermingling of data of widely separated areas, should be avoided.

This is also true with regard to the used nomenclature while often we find connotations such as Eemian, derived from the Northern European area mixted with terms such as Würm and Riss, typical of the Alpine region. Such confusion can be avoided in the future by basing the choice of a classification system on stratigraphical field evidence.

For this purpose, it is noteworthy that in Belgium we deal with the opportunity that the coversand area of Northwestern Europe and the loess area of Central Europe meet with each other; this permits not only investigation of the entire lithological sequences of the periglacial area but also correlation of these various sedimentation systems which ultimately leads to the conclusion that for Belgium the Northwestern European classification system is more suitable. Accordingly, it is more likely to connotate in Belgium the Last Glacial deposits with Weichsel rather than with Würm.

In previous studies, palaeobotanical investigations were seldom systematically linked to litho-stratigraphical studies. It is obvious that problems concerning the base of the Weichsel and the minor climatic fluctuations within the last glacial period can only be disentangled with the help of palaeobotanical investigations.

Also C14 datings, if thoroughly controlled by the field facts, are of great importance, especially for correlations with other regions.

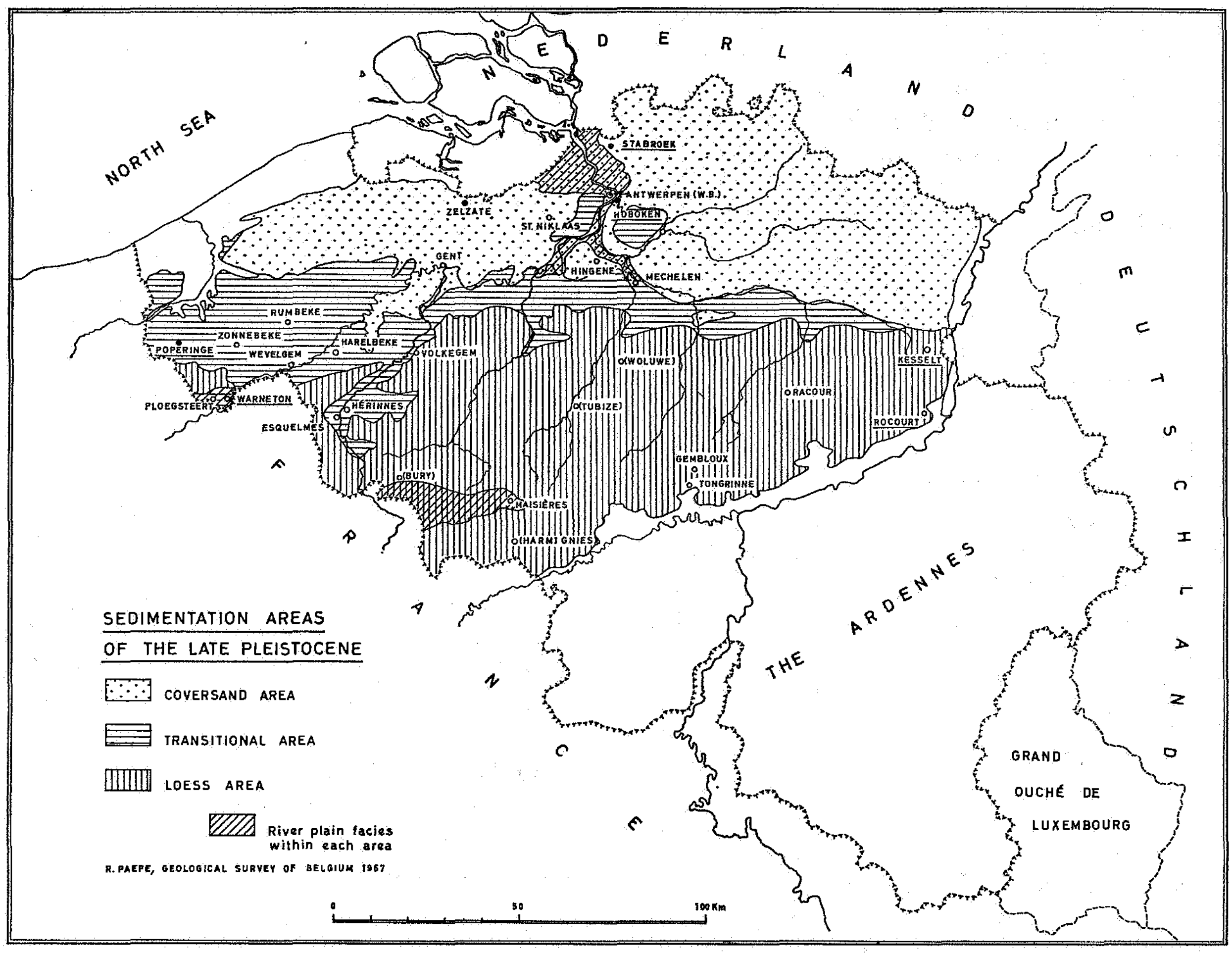

Fig. 1 — Map of the sedimentation areas in Belgium: based on the Map of the Soil Groups of Belgium (R. Tavernier and R. Maréchal, 1959) on the one hand and on section profiles (R. Paepe) on the other side. The localities indicated with a black dot yielded C14-datings whereas those underlined by a straight line were chosen as a type locality. Recording of some profiles is still under progress the name of which profiles is then put between brackets.

CHAPTER 1

THE ROCK SEQUENCES OF THE LATE PLEISTOCENE (R. PAEPE)

1.1. INTRODUCTION.

In Belgium, the Late Pleistocene is represented by periglacial deposits mainly and no direct correlation can be made neither with glacial deposits (moraines, tills) nor with well dated river terraces.

There is, however, a limited area in the Northwestern (coversand) part of the country where fluvio-marine, Eemian deposits occur under a relatively thick (20 m) cover of continental, Last Glacial deposits. This is up to now, the only place in Belgium where the Late Pleistocene deposits as a whole can stratigraphically be assured and can also be linked to one of the existing type areas e.g. the Northern European area.

In order to correlate sections yielded from other sedimentation basins in Belgium, we had to establish *reference levels* within the bulk of the periglacial deposits. Such levels reflect then the major climatic fluctuations causing differences as to the mode of sedimentation, erosion, soil development and vegetation growth. The present study is therefore based on *morpho-lithogical-climatological* field data on the one side, and on *palaeobotanical-climatological* investigations on the other hand. In the present chapter, stress will be laid on the *litho-stratigraphical units* or *rock sequences*.

As one may expect, according to the area which is dealt with, the outlook of the *reference levels* may differ considerably. This can be due to *regional variations of the prevailing climatic conditions* (e.g. humidity versus drought) but also to a *locally bounded topographical position* (valley fillings versus plateau deposits).

With respect to these criteria, three main areas of investigation are set forth, which are thought to form sedimentological-climatological units: the *loess area*, the *transitional area* and the *coversand area* (fig. 1) with the exemption of the Campine region. One may easily find back here the traditional regional subdivision of Western Belgium referred to as loam belt, sandloam belt and sand belt. The latter connotation however differs from ours in that it tacitly is restricted to indicate deposits occupying preferably a plateau position. To the author's knowledge, valley fillings of large thalweg systems, although differing thoroughly from the adjacent plateau deposits, reflect also the climatical conditions of the area to which they belong and often show a more elaborate stratigraphical sequence. Therefore they are studied separately from the plateau sites which are then grouped under the traditional regional connotations.

It goes without saying that, on making comparisons between sections of different areas, one may meet with difficulties caused solely by the local *palaeo-geomorphological aspect* of the deposits. Up to now, too little detail study has been done on this subject. It is, however, of great necessity to fully understand e.g. the *quick lateral changes* in the texture of the sediment. As will be shown later, lateral transition between pure eolian loess loam and pure cross bedded fluviatile sands may occur over less than 1 m distance. This emphasizes immediately the importance of studying *long sections* instead of narrow arbitrarely choosen profiles. In the latter cases, particular aspects of the sedimentation pattern may be erroneously accounted for the general stratigraphy.

In fact, e.g. stronger or less fluviatile activity ranks generally as a parameter for lower or greater continentality of the climate. As a result the presence of such deposits may be representative of the climatical phase which is dealt with and thus also of the position of the stratigraphical boundaries. If now fluviatile deposits happen to occur simultaneously with pure eolian deposits, than one should be carefull with respect to its interpretation. It then may be stated that due to local conditions fluviatile activity in places lasted longer even if the overwhole climatical conditions were favourising eolian sedimentation. T. VAN DER HAMMEN (1957) made this statement for the whole of Western and Central Europe. Later in this volume, we will see that this is also true over relatively short distances, e.g. between the loess area on the one side and both the transitional and coversand areas on the other hand.

1.2. DESCRIPTION OF THE LITHO-STRATIGRAPHICAL UNITS IN THE VARIOUS SEDIMENTATION BASINS.

Whereas for all the pre-quaternary geological formations litho-stratigraphical units are well defined, this is still lacking in Belgium for the pleistocene deposits, even for their uppermost member, the Late Pleistocene. It is true that in the past, number of characteristics of the periglacial deposits have been compiled under lithological denominations but all were more or less biased by their time-stratigraphical significance. A short review of the origin of the nomenclature which is still en vogue to-day, follows hereafter.

A. RUTOT (1897) and J. CORNET (1923, 1927), worked out a litho-stratigraphical division of the Late Pleistocene using the terminology introduced by M. LADRIÈRE (1890) in Northern France. From these authors, R. TAVERNIER (1946) took over the expression «ergeron» and primary applied it solely to the loam deposits of the loess belt. Later (1954), he included in this term deposits from the sandy regions in Western Belgium, which he considered as being of the same age although greatly differing in texture. Still later (R. TAVERNIER and J. DE HEINZELIN, 1957), this term was definitely replaced by purely time-stratigraphical expressions such as «Limon récent 1» (already introduced by J. CORNET, 1927) assembling deposits of different areas which obviously not only varied in texture but also in sedimentation pattern.

F. GULLENTOPS (1954) applied and redefined some of A. RUTOT's lithological units of the Late Pleistocene, such as «Brabantian» and «Hesbayan», with respect to the loam deposits in the loess area. But this system is also found unsatisfactory when making an attempt to group the complex of rock sequences of the transitional and coversand areas. Yet, A. RUTOT (1897) was aware of this problem and introduced names as «Flandrian» to indicate the deposits in the western sandy regions which he thought to be of the same age as the «Brabantian», but presumably of fluvio-marine origin.

Quaternary, particularly Late Pleistocene deposits, are a too delicate system as to the regional diversity of grain size and sedimentation pattern, that grouping under one name of beds which reflect numerous fluctuations of climate and differences of relief is an unefficient procedure for field-geological investigation. Therefore, we looked for and defined for each member of the rock sequence the diagnostic horizon, the latter being characterized both by its similarity and its widespread occurrence despite the region which is dealt with. The entire member is then called after this diagnostic horizon whatever its sedimentation pattern may look like in other parts of the section.

Hereafter, in order to permit easier reading of our descriptions, the terminology of the by us introduced litho-stratigraphical units, is listed in their stratigraphical succession from the top downwards:

1) *Late coversands* and *Stabroek soil;*

2) *a) Coversand 2* or *coverloam 2;*
   b) Desert pavement 3 and *large frost wedge row;*
   c) Coversand 1 or *coverloam 1;*
   d) Cross-bedded sands;

3) *Cryoturbated soil horizon* (*Kesselt - Zelzate soil*) with *desert pavement 2* and a *fine frost wedge row* on top;

4) *Peaty loam formations, Loam formations* or *Sandformations* occasionally with the *Poperinge soil* and the *Hoboken soil;*

5) *Desert pavement 1* and *small frost wedge row;*

6) *Loams and coarse sands* with or without the *Warneton soil;*

7) *Sands and gravels* with or without *Antwerp soil*;

8) *Peat and Gravels* and/or *Rocourt soil.*

1.2.1. THE LOESS AREA.

The loess area tallies mainly with the loam belt of Belgium where eolian sedimentation was the dominant process of the Last Glacial period. As a result the uppermost coverloams are pure loam in texture while underneath sediments of eolian origin occur too but than intermingled with important solifluction beds and locally with gully fillings. Several profile descriptions were yielded from the loam belt by different authors (G. MANIL, 1948-1952; F. GULLENTOPS, 1954 and R. PAEPE, 1965).

Two types of profiles are usually found: one with a thin loam cover (< 1.00 m) and one with a thick pure loam cover (up to about 10 m).

Within this area, the Haine Plain provides profiles from the valley type of loess accumulation.

1.2.1.1. *The Loam Belt.*

Tongrinne.

This locality is of the first type with thin loess cover (fig. 2) (photo 1). R. PAEPE (1966) compared its stratigraphy to the ones described by G. MANIL (1949, 1952) in the Gembloux area and the ones described by F. GULLENTOPS (1954) at Kesselt, Rocourt and Ans.

Generally, the following rocks units can be noticed. At the top of a Saale loess deposit (10), a truncated reddish textural-B-horizon (9) is found. To this horizon the name «*Rocourt soil*» was given by F. GULLENTOPS (1954).

Above the *Rocourt soil* lies a grayish solifluction layer (8), the top of which is darker and contains a high percentage of organic material. The latter is the A horizon of a steppe soil (*) which formed after the initial solifluction period of the beginning of the Weichsel glaciation. Crotovines are found at this level but also in the reddish soil below; this pleads for the autochtonous character of the steppe soil. Earlier, R. PAEPE (1963) has called this humic soil horizon the «*Warneton soil*» after the type locality Warneton (transitional area; see p. 17).

R. PAEPE (1966) showed also the morpho-stratigraphical resemblance of the stratigraphical sequence: red soil/humic soil with the Stillfried A complex of Austria. The *Rocourt soil* tallies then with the lowerlying textural-B-horizon (Göttweig) and the humic horizon (*Warneton soil*) with the upperlying humic horizon of the Stillfried A complex.

On top of the *Warneton soil* a row of *small frost wedges* (7) is found together with a discontinuous pebble band (*desert pavement 1*).

Immediately above, lies a series of *loam formations:* first comes a thin eolian loess bed (6) overlain by a series of fine stratified loam layers, each of which reveal a slight solifluction character (5); actually within these loams, the numerous little frost wedges and occasionally also the somewhat larger frost wedges at its base are all inclined in the same direction while also small cryoturbatic disturbances occur. Sometimes a rolled phyllade may be found in it. The quickly alternating loam layers are finally overlain by another eolian loess (4). The solifluction loam layers form a diagnostic stratigraphical horizon which, as we shall see hereafter, happen to occur commonly in the sections of other areas. They are therefore referred to as *loam formations.*

Follows a *cryoturbated soil horizon* (CRYOT) (3) occupying the stratigraphical position of F. GULLENTOPS' *Kesselt soil.* Morpho-stratigraphically it can be correlated with the Paudorf palaeosoil of Austria (R. PAEPE, 1966). As in the latter locality soil development (brown soil type) is rather weak at this level, a statement which may be also derived from the observations recorded by G. MANIL (1949, 1952, 1955).

On top of the *Kesselt soil* horizon, *large frost wedges* (2) are found. Judging from the surimposition of two such large frost wedges, at least two phases must have occurred (photo 3).

(*) B. BASTIN, from the Catholic University of Louvain, has undertaken the palynological study of the entire loess sequence of this profile. Results will be published later.

A homogeneous eolian coverloam (*coverloam 2*) (1) follows next. The base of this loam may show traces of solifluction although the junction line with the underlying deposits is rather sharp and flat.

Racour.

The profile of the sandpit at Racour is of the type with thick eolian loam cover (fig. 3). Fluviatile *sands and gravels* (10) occur in a shallow depression eroded on top of the Landenian and Tongrian sands (Tertiary) (11). This deposit wedges laterally out into a thin gravelly solifluction layer.

Immediately above follows a row of thin frost wedges (9) with a discontinuous (solifluctated) pebble band on top of it. The latter materializes a sharp subhorizontal discordance line with the overlying brown coloured *loams and coarse sands* (8). These series are strongly disturbed by solifluction and at the top a second row of small frost wedges locally with larger ones occurs (7). It might well be that one deals here with the same *small frost wedge row* observed at Tongrinne above the *Warneton soil*, but the latter is lacking here. Actually, from this level the sedimentation pattern changes considerably and is built up by yellowish coarse fluviatile sand (6) gradually going over into eolian yellowish sandloam (5). The latter is highly cryoturbated, contains numerous little frost wedges, and finally is limited by another frost wedge row (4) with pebble band (*desert pavement 3*). The whole sequence recalls the *loam formations* of Tongrinne, but here they occupy completely the space between the *small* and *large frost wedge rows*. Pure eolian loess beds immediately above or below are lacking.

Next follows a 3 m thick homogeneous mass of eolian yellowish loam (2), the base of which being usually somewhat darker (3). While no periglacial structures are observed in this homogeneous mass, it is not possible to distinguish wether one deals with *coverloam 1* or *2* and therefore these loams have been indicated as *coverloam*.

Volkegem.

This is another profile of the thick loess cover type (fig. 4). It occupies a particular border position at the western edge of the loam belt dominating the Scheldt valley.

The lowermost deposits are *loams and coarse sands* (6) overlying Paniselian sands (8), from which they are separated by a thin (locally twofold) gravel layer (7) (Paniselian sandstones). These beds are composed of light yellowish brown leaflike layered loam mixed with fine brown sandy layers and breccia-like lenses of tiny flat clay pebbles; fluviatile structures and cryoturbation as well as frost wedge structures are common. They do not extend continuously, while these deposits are occupying depressions eroded in the Paniselian sand against which they are laterally wedging out.

They are overlain by another, in places also twofold, thin pebble band (5) (mainly Paniselian sandstone fragments) along which *small frost wedges* (filled with yellowish brown loam) may develop. Where this pebble band (*desert pavement 1*) happens to rest directly on the Paniselian sand, irregular threads filled with yellowish brown loam from above are observed.

Next follows a solifluction deposit similar to the *loam formations* of Tongrinne and Racour, composed mainly of alternating fine yellowish brown loam and sandy layers. Numerous little frost wedges occur in it and sporadically small sandstones fragments may be observed.

At the top of the *loam formations* a row of *fine frost wedges* underlain by a cryoturbation zone, 30 cm in thickness (3), is present. The latter is furthermore characterized by solifluctated yellowish red sand threads and lumps of gray loam at its bottom. As the underlying deposits, this horizon is still unleached and morphologically it reminds the *cryoturbated soil horizon* of Tongrinne. The yellowish red colouring of the sand and the gray colouring of the loam may be caused by a gleyification process.

The sharp regular uppermost limit of the *fine frost wedge row* is sporadically accentuated by the presence of a pebble band (*desert pavement 2*).

Above follows a mass of homogeneous yellowish coverloam (2) of 5 m in thickness, the lower part of which is slightly browner (2') while the upper part is dark brown and entirely decalcified (terre à briques (1)).

1.2.1.2. *The Haine Valley.*

Although surrounded by the loam area, the Haine valley produces a stratigraphical composition which shows great affinity with the transitional area, especially with profiles yielded also from valley systems (the Lys plain; see p. 17).

Maisières.

The excavation for the sluice works of a new section of the «Canal du Centre» offered in the summer of 1966 for only a few weeks, a long and deepgoing profile. Unfortunately enough, at the time, we visited the site, only a few meters of the section were still exposed (fig. 5) so that its interpretation here must be looked at with due reserve. For the sake of completeness it is recorded here, since it offers good insight in the lithological sequence of the valley deposits of the loess area and shows remarkable resemblances with the valley deposits of other area's.

On the Cretaceous (16) lies a yellowish brown loam (15) which is thought to be Saale in age. Indeed, at its top occurs a dark brown soil horizon, slightly gleyified and containing many plant remains. On basis of its stratigraphical position, it may be accounted for the counterpart of the humic soil at Tongrinne (*Warneton soil*) (14). At this level, also frost wedges may occur.

The *Warneton soil* is overlain by a homogeneous dark gray loam (13). The upper boundary of this loam coincides with another, discontinuous frost wedge row (12). Solifluction beds were not observed but its stratigraphic position is favouring correlation with the so-called *loam formations.*

Next follow coarse *cross bedded sands* (10) with pure gravelly layers, composed of rolled pieces of Cretaceous chalk and phtanites at the bottom (11). In our profile, they are the diagnostic horizon, especially when compared with sections of other valley deposits (Zelzate, see p. 25).

The whole seems truncated by a continuous stone line with little *frost wedges* (9) whereupon follows a series of sub-horizontally fine layered loams (8 through 5) alternating with isolated lenses of sands, revealing the *coverloam 1* facies of the transitional area.

The latter assumption is supported by the presence of bound cryoturbation in its upper part, a feature, well known from the top of both *coverloam 1* and *coversand 1*, as we shall see later.

Gray sandy loams (2) overly the cryoturbated horizon and are characterized by the presence of numerous calcareous concretions. They are referred to as *coverloam 2* deposits.

1.2.2. The Transitional Area.

The transitional area coincides for its greater part with the sandloam region of Belgium. Here the *coverloam 2* of the loess area is eighter strongly intermingled with sandy layers or yet may be entirely sandy in texture (*coversand 2*). The *coverloam 1* may be a pure loam or composed of quickly alternating sand and loam layers (*coversand 1*), locally showing a lateral fluvial or even fluviatile facies (*cross bedded sands*).

The underlying deposits show an outspoken fluvial or/and solifluction sedimentation wherein pure eolian deposits are relatively scarcely present. These deposits attain a greater thickness than the overlying coverloam series and also than their counterparts in the loess area.

The difference between the loess area and the transitional is thus double: change in texture of the cover deposits and a decrease of the degree of the eolian sedimentation pattern. Fluvial-solifluction processes and eolian sedimentation, however, seem to be in a delicate adjustment in this area.

Our profile descriptions are yielded from two different landscape units: the Lys alluvial plain and the adjacent sandloam belt surrounding Flemish Hills.

1.2.2.1. *The Lys Alluvial plain.*

The Late Pleistocene deposits of the Lys alluvial plain, extending between the Flemish Hills and the Artesian Plateau are characterized by: the common flat horizontal bedding with sharp junction lines, the high content of reworked fluvial Ypresian clay in the *coverloam 1* and the limited thickness of the *coversand 2* (Warneton, Ploegsteert).

North of the Flemish Hills, the *coverloam 1* has made room for coarser textured and more eolian sediments building up the *coversand 1* while *coversand 2* remains limited in thickness. (Wevelgem, Harelbeke).

Previously described profiles (R. PAEPE, 1963, 1965) will be reviewed and new sections presented.

Warneton.

The so-called normal profile is found in the right part of the east side section (fig. 6, photo 2).

On top of the Saale loess (19), the Eemian interglacial deposits are composed of peat filling undeep ravinations gullies (see R. PAEPE, 1965) and of a strongly weathered palaeosoil (18) outside these ravinations. Along the slope down to the bottom of the ravination, the palaeosoil is a strongly gleyified, hydromorphic soil becoming rapidly a typical reddish *Rocourt soil* when climbing up along the upper limit of the Saale loess. The upper part of the reddish soil remains however gleyified (17) (photo 4).

The *Rocourt soil* is overlain by a humic horizon (15) which has earlier been called *Warneton soil* by R. PAEPE (1963, 1965, 1966). Between the two soils, a brown gray sandy loam (16) with cryoturbatic involutions and solifluction structures may occur. If lacking, disturbances are found along the junction line of the two palaeosoils and then also the *Rocourt soil* is deeply affected by solifluction.

Next comes a yellowish brown sandy loam (14) with a dense row of fine frost wedges (13) at its top.

Follows a white yellowish loam (12) bearing along its upper limit also a fine *small frost wedge row* (11) but differing from the underlying loam by its more outspoken fluvial character. Stress must be laid on the aspect of the plane horizontal view of the *small frost wedge row* horizon. It reveals a regular rectangular pattern, the main branches of which coincide with the major wedges and the links of second, third and more order, with the finer fissures (photo's 5, 6 and 7).

The whole sequence is cut by a pebble band (10) which locally rests immediately on the *Warneton soil* and recalls then undubiously the position of *desert pavement 1* of Tongrinne.

The above described series now grow laterally out into a pure fluviatile system filling up ravination (fig. 6 left part and fig. 7). This is mainly due to the increasing thickness of the yellowish fluviatile loam (12) whereunder the yellowish loam (14) and the *Warneton soil* (15) are wedging out. At the same time the uppermost *small frost wedge row* (11) becomes very strongly developed whereas the lowermost goes over into a system of cryoturbatic involutions. Above and below the latter, new humic horizons appear and are considered as recurrences of the *Warneton soil.*

Finally, the entire formation makes laterally room for strongly fluviatile *loams and coarse sands* (fig. 7 and also R. PAEPE, 1963, 1965), characterized by at least two bands of coarse sands below which lenses of clay pebble breccia may occur.

The stratigraphical sequence is continued by a series of *peaty loam formations* (8) characterized by numerous little frost wedges, all inclined in a same (solifluction) direction. The base of this complex is often humic and is referred to as *Poperinge soil* (9) (see p. 20). These series reveal great similarity with the *loam formations* of Tongrinne but again, here they attain a much greater thickness and are not enclosed between pure eolian deposits.

The top of these series is marked by another pebble band (*desert pavement 2*) overlying a *fine frost wedge row* (7); seen from a perpendicular angle of view, one can only observe a sandy cryoturbation zone. Underneath, remnants of a (textural) B horizon may occur (R. PAEPE, 1965) occupying then the stratigraphic position of the *cryoturbated soil horizon* of Tongrinne.

Hence, from a litho-stratigraphical point of view, it is noteworthy that contrary to the Tongrinne section pure eolian deposits have made entirely room here for solifluction-fluvial deposits between the *cryoturbated soil horizon* and *desert pavement 1.*

Higher in the section the sedimentation pattern changes completely. A thin layer of fluviatile *cross bedded sands* (6) is overlain by a yellowish brown loam (5) composed of quickly alternating eolian loam layers with fine fluvial clay layers. The latter are derived from the Ypresian clay outcropping in the adjacent Flemish Hills. This facies is typical for the *coverloam 1* series in the Lys plain.

In the upper zone of this deposit, undulations (4) are very common extending underneath a *large frost wedge row* (3) wherein prominent cryoturbations sacks do also occur. Both frost wedges and sacks are filled with sand derived from the overlying thin layer of *coversand 2* (2) at the base of which eolised pebbles (probably *desert pavement 3*) are often found.

Finally, late glacial or/and holocene alluvial clay deposits (1) close the stratigraphical sequence.

Ploegsteert.

The profile recorded by R. Paepe in 1961 is used here and reviewed (R. Paepe 1963, 1965) (fig. 31).

The difference with Warneton lies in the fact that the *desert pavement 1* is lacking in this section. Here a thin loess loam bearing a humic layer (*Warneton soil*) on top of it, lies on the Eemian interglacial hydromorphic soil. Next follows a sandy layer immediately overlain by another humic layer (*Poperinge soil*), occurring at the base of the *peaty loam formations*. Further upwards the same stratigraphy is found as at Warneton.

Wevelgem.

This sandpit has temporarily been opened by Sogetra, S.A., during the E3-highway works between Courtrai and the French border (fig. 8). It yields a section in the Late Pleistocene deposits of the Lys valley north of the Flemish Hills. The whole profile is about 150 m long and 7 to 8 m deep. The stratigraphical sequence is rather constant over its entire length and therefore it was sufficient to reproduce only a «narrow» profile of it.

Geoelectric soundings (R. Paepe, 1967) located the base of the pleistocene at an absolute depth of — 4.00 m so that the outcropping 7 metres represent a minor part only. Nevertheless, the major stratigraphic sequences of the Weichsel are comprised within this part and this is an important observation.

The *loams and coarse sands* (18) form a blue greenish sandy loam with more pale sandy and darker loamy thick lenses mixted within the mass. These series show a rather constant facies which may extend considerably downwards since the whole behaves as a homogeneous mass on the geoelectric curve down to the Ypresian clay. Its upper limit is determined by the *small frost wedge row*.

Hereupon follow the *peaty loam formations* composed of an alternation of fine sandy and sandy loam beds (17-12). There is however, possibility to trace a systematic recurrence of four similar sequences: peaty solifluction loams gradually becoming more fluviatile, overlain by a white sand layer or veneer and a row of fine frost wedges with fine pebble band consisting mainly of Paniselian sandstone fragments. Sporadically, little frost wedges and also sandstone debris may occur within the mass of a bed. Two well developed humic bands occur at respectively 13.25 m (16) and 14.55 m (base of 12) and may represent successively the *Poperinge* and the *Hoboken soils.*

Finally another strong humic horizon closes the sequence at the top and reminds undubiously the *cryoturbated soil horizon* (11) both by its morphological aspect as well as by its stratigraphic position. It is disturbed by a dense *fine frost wedge row* overlain by a thin veneer of white, fine eolian sand (*desert pavement 2* ?). This series of *peaty loam formations* is with regard to the sedimentation pattern, more closely related with the ones observed at Poperinge, Rumbeke and Ghent (see later) than with those observed at Warneton and Ploegsteert.

Also the *coversand 1* pattern, extending further upwards almost until the surface, differs entirely, with respect to both texture and pattern. Striking resemblance of this sequence of fluvial structured alternating sands and loams—especially by the presence of irregularly stratified bands of clayey loam (3) with (actual?) rootlets—overlain by *large frost wedges,* appears then to exist with the *coversand 1* series observed at Ghent (Sifferdock) in the Flemish Valley (see p. 26). Also the gray loam layer (6) disturbed by cryoturbatic undulations recalls a phenomenon which is found back in another *coversand 1* exposure of the Flemish Valley at Zelzate.

The *large frost wedge row* starts to develop within the overlying loamy yellowish sands, part of which is to be considered as *coversand 2.*

Harelbeke.

Another section in the Lys plain north of the Flemish Hills was opened at Harelbeke during the installation of a conduct between the Gaverbeek and the river Lys (fig. 9). But for some minor differences the profile shows much resemblance with the one observed at Wevelgem so that it may be concluded as to the general presence of the same sediment series in this part of the Lys valley at least for its upper part.

Above a greenish brown loamy fine sand (14) which might be part of the *loams and coarse sands,* occur the *peaty loam formations.* They show a most typical facies very similar to the one observed at Ghent in the Sifferdock. Here four well separated series (13, 12, 11, 10) of alternating brown loam and pale sand layers are present with each time a row of fine frost wedges overlain by a veneer of fine white eolian sand at the top of it.

They are followed by a thick bed of *cross bedded sands* composed of gray brown fine sand (9, 7) and of grayish white coarse shell-bearing sands (8) occasionally with little frost wedges.

Hereupon lies a homogeneous sand bed (6) with, however, numerous diffuse ripplemarks zones followed by a brown disturbed sandloam layer (5) overlain in turn by a yellowish oxydized fine sand (4) layer. The whole is referred to as *coversand 1.*

Along the upper limit of the latter series, occurs the *large frost wedge row* which pearces rather deeply (1 m) into the underlying deposits. This row is overlain first by a continuous greenish gray clay (3) with irregular stratification (recalling the clay filled gullies above the frost wedge of Zelzate), and second by a brown medium fine sand with loamy lenses (2). Both deposits build up the *coversand 2* or at least part of it. For it is not sure whether gray clayey sand with oxydation mottles are to be classified with the *coversand 2* or yet, with the Late Coversand series.

1.2.2.2. *The Sandloam Belt.*

The here reported profiles are yielded from the sandloam belt north of the southwestern extension of the Flemish Hills in Belgium. *Loams and coarse sands* and *peaty loam formations* fill up broad depressions between the buried Tertiary humps while *coversand 1* and subsequently the younger overlying deposits extend far over the hill plateaus and may completely cover them.

With the exception of Zonnebeke, new recently recorded profiles of the already published ones are here presented.

Poperinge.

The lowermost pleistocene deposit overlying the Ypresian clay (12) is a blue-gray Saale loam (11). Its upper limit traces the valley form wherein the sediments of the Last Glacial were deposited. To the south of the left part of the profile (fig. 10) the *Rocourt soil* appears on the uprising Saale loam; downslope it goes over in a gleyified, hydromorphic soil and finally disappears where ravinating overlying deposits attain their maximum depth.

As the hydromorphic interglacial soil appears, a humic horizon (*Warneton soil*) (10) starts to develop just above it. It is formed in a solifluction, sometimes a fluvial deposit and becomes extremely peaty in the lower parts of the valley. There also, a thin gravel layer separates it from the underlying Saale loam (fig. 11). The moreover, it can disappear and fall apart into rolled peat lumps mixed within a gravelly sandy deposit. On the slightly higher situated valley borders this peaty horizon is disturbed by cryoturbation and also frost wedges may be present at its base.

Next follows a series of *loams and coarse sands* (9). Usually there are two heavily cryoturbated (gravelly) sand bands separated by a loam bed also showing strong cryoturbatic disturbances. The latter become the dominating feature to the south of the profile (fig. 11) where they also wedge out against the *Warneton soil.* They remind the large cryoturbatic involutions mentioned at Warneton, especially since underneath the clay pebble breccia lenses with Fe/Mn concretions are also found.

Finally, these series end up with a faintly developed *small frost wedge row* (sometimes only a cryoturbation layer) while *desert pavement 1* is lacking here.

Thereupon follows a peaty horizon (8) more prominently developed than its humic counterpart found above *desert pavement 1* at Warneton. It remains constant untill it wedges out to the south against the peaty facies of the *Warneton soil.* The C-14 dating of this horizon is 45.600 $\pm$ 1500 y.B.P. (GrN. 4856). We will call this level the *Poperinge soil* (photo 8).

The *peaty loam formations* (7) covering the former peaty horizon differ from the ones observed at Warneton and Tongrinne, in that they are commonly more darker (more humic) and further composed of irregular layers with fine ripple-mark structures as well as layers affected by small cryoturbatic and solifluction irregularities. Whereas the underlying *loams and coarse sands,* were connected with quick running water, these deposits seem rather derived from a superficial water sedimentation.

The *cryoturbated soil horizon* usually found in the very upper part of the last mentioned series is here represented only by a small discontinuous cryoturbated horizon or a frost wedge zone. Real peat layers caught in fluviatile layers may, however, occur locally and then be correlated with the *Kesselt soil* formation of other places.

Again, these series wedge out to the south (fig. 10) and may even partly be eroded by the overlying *cross bedded sands* (6). With this respect it is important to notice that at this stratigraphical level, the topography has become almost flat.

In the *cross bedded sands* three subdivisions can be made. There is a lower part, which as long as it rests on the *peaty loam formations,* shows the cross bedded structure (6). This is surprisingly so when its extension is restricted to the valley boundaries of the underlying deposits. Once outside these buried valley limits, when overlying the *Warneton soil,* they go very rapidly over (in less than 0.50 m distance) into a solid mass of blue gray eolian loam and further away, into a mottled yellowish gray sandy loam. In the extreme southside of the profile (fig. 10) the latter mentioned facies covers directly the *Rocourt soil.* At this very place we observe the first opening of a large deepgoing frost wedge starting at the top of the loam layer. The loam layer is therefore referred to as *coverloam 1.*

It must be noticed that the valley form outlined against these lowermost *cross bedded sands* is already by far more shallow than the one filled with the underlying Late Pleistocene deposits.

A second *cross bedded sand* layer (5) can be distinguished going over to the south and to the north in a gray loam or a yellowish brown sand-loam. The top of this loam coincides with a stone line which at one place is interrupted by a frost wedge (left part of profile) (fig. 10). Also the large frost wedge seem having been reopened at this level.

Next follows a pebble band immediately overlain by fine layered sand (4) laterally also going over into a *cross bedded sand* deposit which attains a considerably thickness towards the middle of the profile. There, it fills a flat ravination eroding part of both two other underlying cross bedded sand deposits. Frost wedges and cryoturbatic features occur at different levels in this very uppermost part of the *cross bedded sands* giving proof of the increasing severeness of the cold climatic conditions. Towards the north end of the profile, the third cross bedded sand bed goes laterally over into quickly alternating yellowish brown sand and loam characterized by the occurrence of a great number of pipestems and of Fe/Mn concretions (fig. 11). This facies recalls the typical *coversand 1* structure observed elsewhere in the area.

In the very middle of the profile, where the valley form is developed at its best, it is difficult to distinguish the three cited horizons of *cross bedded sands* because of their intermingled character. But still one may observe in the upper part, more loamy lenses than in the lower part which is outspoken gravelly. Also it can be stated that the lowermost *cross bedded sands* broaden out more widely, than the upper ones. It looks as if the fluviatile nature of the deposit got more and more restricted as cold conditions increased.

The series is bordered by a *large frost wedge row* bearing a pebble band (*desert pavement 3*) on top of it. This pebble band goes locally over into small ravination gullies (R. PAEPE, 1963).

Immediately above *desert pavement 3* lies a gray brown sandloam (3) formation which off the underlying *cross bedded sands* may hold some clayey lenses (cfr. Harelbeke) and become a mottled yellowish loam (*coverloam 2*) on the highest part of the profile.

Usually, there exists a fine frost wedge row on top of the *coverloam 2* thus separating it from a fine layered overlying yellowish sand (2). On the latter lies another fine frost wedge row upon which a sandloam (1) top cover is laid down.

From this profile it can be deducted that there is a gradual change in the erosion-sedimentation pattern and palaeogeomorphological aspect of the deposits throughout the Weichsel Glacial. The *loams and coarse sands* give still proof of important fluviatile activity (gully erosion) which becomes strongly reduced during deposition of the *peaty loam formations* (more sheet erosion). Also sedimentation of the lowermost series was mainly confined to the gully system while it becomes more like a sheetwise deposition during the following depositional phase. Eolian sedimentation is dominant as of *coverloam 1* although for local climatical reasons fluviatile activity may have gone on simultaneously. No real gullying has taken place and the *cross bedded sands* are considered as a lateral simultaneous meltwater deposit of the pure eolian loess with which they are interfingering.

Rumbeke.

The lowermost pleistocene beds rest on Ypresian clay (Eocene) (15) the contact of which is a regular junction line characterized by a discontinuous medium fine gravel layer (fig. 12). These beds are composed of gray blueish sandy and clayey loam showing fluvial stratification and bearing occasionally humic lenses. In places these series become at the bottom outspoken fluviatile in nature and gravel lenses may then be intercalated. Also, a little beneath the middle of the deposit a fine frost wedge horizon was observed. It recalls the aspect of the Saale deposits observed at Warneton and more especially at Poperinge (14).

A continuous peaty horizon (*Rumbeke 1*), undoubtedly developed in a solifluction deposit, with a thickness of 0.50 to 1 m overlies the Saale beds (13). It is overlain by a compact blue clay which laterally may develop into an entirely sandy facies (12).

Between 12 and 24 m of the section another distinct peaty horizon is developed on top of the blue clay. To the east it is eroded whereas towards the west it is undoubled in an upper (11) and a lower member (10). As of then a distinct, thin peat band showing mini-cryoturbatic disturbances coincide with the upper limit of each member and between the two members green silty sands are intercalated.

R. VANHOORNE (p. 61 this volume) shows the presence of an Eemian flora within the lower peaty member (*Rumbeke 2*) and attributes to the upper member an early Weichselian age (*Warneton soil*). Thus we deal here with the particular situation of a cold peat, overlying a warm peat deposit. Were it not of the intercalation of the green silty sand (11), distinction in the field of two different deposits would be entirely impossible. Actually the autochtonous character of the *Rumbeke 2* layer is not sure.

The sequence composed of the *Rumbeke 1* peat, the blue clay and the *Rumbeke 2* peat are hitherto jointly considered Eemian in age and are referred to as *peat and loams* (a variation of the *peat and gravels*).

The *loams and coarse sands* (10, 11) develop laterally from the upper peat member and green silty sands. At the very west end of the section they are divided into two parts by a cryoturbation horizon below which sometimes a peaty thread in a solifluction deposit is observed. Hereunder, gray fluviatile loams separated by two sandy layers occur. Above the cryoturbation horizon alternating loams and sands carrying some peaty bands are present. The lithology reflects exactly the one observed in the *loams and coarse sands* of Poperinge.

East of the peaty beds the *loams and coarse sands* appear as a gully deposit ravinating the peat. At their base, clay pebble breccia lenses (cf. Warneton and Poperinge) are observed, just underneath the sandy bands, assuring the stratigraphical position of this formation. Due to a ravination of the overlying deposits, the *loams and coarse sands* series thins considerably out in the middle of the section where they also lie immediately on the lowermost peaty deposit. Further to the east, they climb up again on top of the reappearing blue clay.

Back to the very west side of the section, which is in fact the normal profile, above the just described series, follow the *peaty loam formations* (9) and (8). At the bottom, the *Poperinge soil* is present as a weakly developed peaty horizon. Above it at least four series of solifluction and fluviatile, fine stratified layers follow each time with a peaty horizon at the bottom and fine frost wedges at the top (9). Sometimes a very fine pebble band occurs along the upper junction line. The very upper part of the peaty loam formations is composed of a pale grayish fine layered silty loam (8).

Below the latter mentioned layer, the *peaty loam formations* go laterally (towards the east side of the section) over into a pale green silty sandy loam with very fine stratification. The peaty levels disappear gradually and at about 20 m there is even a sudden change in the sedimentation pattern. As of then, a cryoturbated solifluction deposit with humic paralelly inclined tongues at the top, appears.

The uppermost pale grayish member (8) of the *peaty loam formations*, also goes laterally over into a complex of lowerlying fluviatile green gray loam (8*b*) and upperlying pale brown loam (8*a*). Both ravinate the underlying lowermost part of the peaty loam formations and then a thin gravel bed is found at the junction line. Solifluction horizons occur within the bulk of these beds as is shown by the paralelly inclined tongues of reddish loam at the contact between the green gray and brown beds.

Finally in the outmost eastern part of the section, bound cryoturbations were found in the very upper part of the pale brown beds as well as clay pebbles and peaty lumps.

It must be noticed here that without the normal profile at the very west end it would have been almost impossible to recognize the *peaty loam formations* in this section. The structure of the *peaty loam formations* at this very place reveals and resembles entirely to the one observed for the same series at Poperinge.

The *cryoturbated soil horizon* occurs as a double humic layer (7) overlying the *peaty loam formations*. The bottom humic layer shows cryoturbatic disturbances in the eastern part of the section and at the same time it becomes more (fluviatile) sandy and even gravelly. The top humic layer carries also cryoturbations which locally are replaced by a fine frost wedge row with a pebble band (*desert pavement 2*) on top of it.

Immediately above this desert pavement, lies the *coverloam 1* which in the lower part is a gray subhorizontally stratified loam (6) and in the upper part a yellowish brown mottled loam with reddish pipestems and regular bound undulations (5) (cf. respectively Poperinge and Warneton).

A row of *large frost wedges* (4) occasionally accompanied by frost pockets and overlain by a pebble band (*desert pavement 3*) lines out the junction with the overlying, mottled *coversand 2* beds (3).

The sequence ends with a fine stratified yellowish brown *late coversand* (2) separated from the underlying *coversand 2* by a fine frost wedge row with a pebble band on top of it.

In the *late coversands* the post-glacial soil (gray brown podzolic) (1) has developed.

Zonnebeke.

As this section has been published earlier (R. Paepe 1965), it figures only on the general scheme (fig. 31) and its stratigraphical interpretation is reviewed here in accordance with the present lithological units.

The uppermost *large frost wedge row* separates *coversand 2* from *coverloam 1*, the latter being characterized by the yellowish brown loam facies with undulations, already observed at Poperinge and Warneton.

The sandy body below *coverloam 1* broadens out laterally into a series of loam and sand layers with numerous, little frost wedges (*peaty loam formations*). Towards the bottom, a cross bedded structure appears and to the very base two gravelly layers separated by a brown humic loam (*Poperinge soil*?) occurs. These series are both under- and overlain by a frost wedge row with pebble band, the lower one of which is considered as the *small frost wedge row* with *desert pavement 1*. Actually, underneath follows a thick grayish loam bed with sandy lenses in the upper part, showing great resemblance with the *loams and coarse sands* series.

Notice, also, that the present morphology recalls the litho-stratigraphical succession of the section at Maisières in the Haine Valley.

1.2.2.3. *The Scheldt Plain.*

It is known from several borings in the Scheldt valley, south of Ghent, that the Pleistocene deposits reach a great depth and are rather similar in composition to the ones occurring in the Flemish valley north of Ghent. Fortunately, recent observations could be made in natural sinkholes occurring on both sides of the present course of the river.

Esquelmes (West-bank).

The diagnostic horizon (fig. 13) occurs at 2.60 m below the surface and is composed of a thin pebble band (*desert pavement 3*) underlain by the *large frost wedge row* which coincides with the top of the underlying *coversand 1*. The latter following below shows the typical bandering of alternating loamy and sandy layers (9) becoming gradually towards the bottom a homogeneous sandy loam (10). (Cf. Poperinge, Rumbeke, Zonnebeke.)

Above *desert pavement 3* follows a fine veneer of sand (8) the top of which is cryoturbated. Next follows a yellowish fine homogeneous (eolian) sand (7) building up *coversand 2*.

The next series (*late coversand 1*) are composed of brown loams with fine sand layers (6) showing in the upper part traces of solifluction overlain by a fine diffuse frost wedge row (5). Many plant remains are observed in the loamy layer occurring at the upper limit of the unleached lower part. Since little if any vegetation is known to exist in the *coversand 2* they are attributed to the Bölling oscillation.

A brown loamy sand (4) (*late coversand 2*) follows next, the top of which is overshadowed by the presence of the post-glacial (gray brown podzolic) soil (1,2,3). Whether holocene deposits are present or not is difficult to elucidate.

Hérinnes (East bank).

A profile similar to the one described just above, is found on the east bank of the river (fig. 14). Here also the diagnostic horizon is the *large frost wedge row* overlain by *desert pavement 3* and next by a cryoturbated horizon (10). The whole occurs at about the same depth below the surface (1.00 m) as their counterparts at Esquelmes.

Towards the bottom a yellowish loamy sand (11) (*coversand 1*), rather homogeneous in texture, is found, while above the diagnostic level, sand and loam layers building up *coversand 2* (8 and 9), are present.

The sequence is continued by the *late coversand 1* series composed of a brown clayey loam (7) wherein many plant remains occur and above it, a solifluctated loamy sand (6).

The overlying *late coversand 2* series are, as at Esquelmes composed of several layers of fine sands (5, 2) interfering with, clayey lenses (4) bearing in the upper part the post-glacial gray brown podzolic soil (1,2,3).

Between the two *late coversand* deposits no frost wedges have been reported and the distinction between the two series was based on their litho-morphological resemblance with the section of Esquelmes.

1.2.3. The Coversand Area.

The coversand area extends in the north of Belgium north of a line, running in a west-east direction from the coastal plain via Ghent and Mechelen to Diest and Hasselt. East of Ghent, the southern boundary is formed by the rivers Scheldt, Rupel, Dijle and Demer. In this area, the facies of *coversand 2* remains the same as in the transitional area but the facies of *coversand 1* is now characterized by its outspoken sandy nature. No real loam beds occur in it but for a few sporadical thin loamy lenses.

Below, the *peaty loam formations* and *loams and coarse sands* show a similar sedimentation pattern as in the transitional area; further down, however, another Weichselian deposit is usually well developed: the so-called *sands and gravels*.

Recently, tunnelworks at Zelzate and Antwerp and dock excavations at Ghent, permitted observations down to the tertiary substratum. The profiles yielded from this area bear great importance because of their striking resemblance with the Late Pleistocene deposits of the Netherlands.

1.2.3.1. *The Flemish Valley.*

Zelzate.

At the top of the Barton clay (section 3) (fig. 17) lies a coarse gravel (22) of almost 3 m in thickness within which the guide fossil of the marine Eemian deposits *Tapes senescens* was found in situ together with *Corbicula fluminalis*. Earlier the present author drew attention to the widespread occurrence of these gravels in North-western Belgium and their correlation with the «Senescens Sande» of Northern Germany (R. Paepe, 1966). This gravel yielded also vertebrate elements as well as detritus peat in little ravinations at the top of it (R. Vanhoorne, p. 62) and therefore they are referred to as *peat and gravels*. A horizontally stratified series of fine sands and clays (21) overlying the gravel follows up to — 8 m where they are limited by a sharp subhorizontal line of discordance. At the same level about 100 m to the west (section 2) (fig. 16) (photo 11) a reddish clay horizon (19) also truncated by the same discordance line and overlying a greenish gray loamy sand is present. It is considered, because of its position with regard to the Eemian gravels and its degree of soil development, as the counterpart of the *Rocourt soil* in this area. We thus deal here with the corner stone of our stratigraphy, assuring definitely the Eemian age of the *Rocourt* soil. Furthermore the deposits between the gravel beds and the — 8 m level are locally incised by large shallow ravinations (20) which according to their position and morphology are considered as belonging to the Weichsel glacial period. W. H. Zagwijn (1961), from investigations at Moershoofd and Terneuzen reported also Weichselian and Eemian deposits within short distance at equal heights.

The next series are the *loams and coarse sands*. In section 5 (fig. 18) this facies (16 + 17 + 18) compares easily with Poperinge while in sections 4 and 2 the sandy layers have disappeared and then recall Zonnebeke and Maisières. In the sections 4 and 2 they form two loam deposits each time with a humic shellbearing horizon at the top of it.

From now on we follow the succession on sections 1 and 2 (fig. 15 and 16) (photo's 9 and 11). On the highest humic horizon follows a solifluction deposit (15) composed of quickly alternating sands and loams showing an astonishing resemblance with the solifluction layers of Tongrinne. As at the latter locality an eolian loam deposit, shellbearing at its base (14), is overlying the solifluction layers but in its very upper part a peaty horizon has developed with bound cryoturbatic disturbances. Next follows another cryoturbated peaty horizon (12) which was dated 28.200 ± 270 y.B.P. (GrN-4783) a dating which compares easily with the one obtained from the Paudorf interstadial in Austria (J. Fink, 1959, 1962). Since it is the first time that an absolute date is obtained in Belgium for this important interstadial we introduced the name *Zelzate soil* for it. Now the question arises whether or not the *Zelzate soil* is the equivalent of the *Kesselt soil*?

According to its morphology and its end stratigraphical position above the solifluction loams and loess deposits, the *Zelzate soil* tallies perfectly with the *cryoturbated soil horizon* observed at Tongrinne, whereas the underlying loams and loesses build up the *loam formations* or better, because of their peaty character, the *peaty loam formations*. The cryoturbated peat horizon immediately below the *Zelzate soil* points then for a stratigraphical position similar to the *Hoboken soil* (see p. 30 this volume).

It then is a matter of course to correlate the humic horizon, immediately underlying the solifluction deposit, with the *Poperinge soil.* At Moershoofd, W. H. ZAGWIJN mentioned at the same height a humic horizon dated 44.500 y.B.P. and at 1 m beneath it, another humic horizon dated 46.500 y.B.P. We think, however, that the lowermost humic horizon (17), because of its position within the *loams and coarse sands*, is much older: *Warneton soil* horizon.

On the *cryoturbated soil horizon* follows first a fine sand layer with peaty threads (11), than more than 1 m of *cross bedded sands* (10). The high content of reworked tertiary shells (i.e. *Cardita planicosta*), sandstone and flint fragments let no doubt about their fluviatile origin whereas the large frost wedges which occasionally occur, show that the climate was colder than during deposition of the sediments below the Zelzate-Kesselt horizon.

Fine eolian yellowish and green coversands (10) overlie the *cross bedded sands* and are bordered at the top by a sandloam layer (10) limited at the top by a *large frost wedge row* and a pebble band (*desert pavement 3*) (9). It can easily be seen that this pebble band forms a discordance surface cutting in places clayey depressions at the top of the sands. This *desert pavement 3* and the lower lying cryoturbatic sandloam layer are known to lie upon each other in the coversand series of the Netherlands (*). The complete series of bed 10 build up *coversand 1.*

Next follow fine grayish sands (8) usually with fine stratification, slightly loamy and in the upper part cryoturbated, somewhat peaty or humic at their base; they build up *coversand 2* previously, generally considered as earliest Dryas.

Several peaty bands (6) follow on *coversand 2* and were dated 12.300 ± 100 y.B.P. (GrN-4782) an age which tallies perfectly with datings of the Bølling oscillation in the Netherlands and Denmark and also with previous datings yielded at Stabroek, by F. DE CONINCK, P. GREGUSS and R. VANHOORNE (1966) (*Stabroek soil*). Above lies a homogeneous white fine sand formation (5) which is undoubtedly eolian (*late coversand 1*). It is overlain by a more yellowish fine sand (3) separated from the previous one by a line of discordance and a zone with rootlets (4) and bearing the post-glacial podzol (2) in its upper part. It is possible that the zone with rootlets witnesses the presence of the Allerød oscillation. Then the uppermost, eolian sands (3) are to be accounted for the *late coversand* 2.

Ghent (Sifferdock).

A very similar stratigraphy is found back in the profile of the Sifferdock works in the Ghent harbour. An idealised section was earlier published by G. DEMOOR (1963). Our section is localised nearby the junction with the Ghent-Terneuzen canal (fig. 19).

The Late Pleistocene sequence starts again with the *peat and gravels*, the detailed description of which follows hereafter. At the very bottom a solid clayey peat block (24), Eemian in age (R. VANHOORNE, p. 65), is found resting irregularly on pale greyish sand. In earlier sections this was also found on Paniselian sand (R. VANHOORNE, p. 65). It is ravinated by overlying gravels (23) and fine sands (22). In the latter, thin, peaty layers occur in places and sporadically also shells. A great amount of clay pebbles are intermingled with the sand. Another coarse sedimentation, cutting the underlying deposits along a sharp discordance line follows and is built up by several coarse gravelly layers containing a great abundance of shells (whereunder the guide fossils of the Eem period: *T. senescens var. eemiensis* and *C. fluminalis*), vertebra fragments, rolled peatlumps, sandstones, quartzites and flints (21). As we mentioned earlier, these gravels with the guide fossils are a widespread feature in this part of the country and therefore we think that they occur in an autochtonous position. They are overlain by a fine sand series (20) occasionally with shell bearing lenses, separated by another line of discordance from the

(*) This was kindly reported by W.H. ZAGWIJN on excursion at Zelzate.

overlying deposits. According to the floristical and faunistical elements of these beds, they are considered entirely as of Eemian age.

Peaty loam formations occur here in their most diagnostical aspect easily to compare with the normal profiles of Rumbeke, Harelbeke and Poperinge. They are composed of four distinguishable horizons (19 and 18), each starting with fluviatile featherlike structures and terminating with a row of little frost wedges overlain by a coarse sand layer at the top. The base of this formation erodes in large, shallow valleys (100 m and more) the top of the Eemian explaining the absence of the *loams and coarse sands* series. The structure of the *peaty loam formation* reminds again a calm superficial water sedimentation, periodically interrupted by a short emersion during which a thin eolian cover (sand layer = local desert pavement) was deposited. Fluctuations of cold humid and cold dry conditions seem to have occurred commonly during this period.

Very fine layered, greenish (17) and yellowish (16) sands deposited in large shallow valleys erode the *peaty loam formations* from which they are separated by a sharp discordance line. *Cross bedded* (snow melt water) *sands* (15) are overlying the fine sands and contain a high number of flint debris, tertiary reworked shells and clay pebbles. Sporadically large frost wedges and large loam lenses may occur, revealing the cold conditions during which this sedimentation took place.

A solifluction horizon (14) separates the *cross bedded sands* from a series of alternating sands and loams (13 and upwards); the latter are without any doubt of eolian origin although fluviatile structures dominate generally the pattern. Beneath a horizon with dropping structures (7) number of shell layers are present while above this horizon, the deposit is leached and contains numerous little frost wedges. Finally, needle-like deepgoing frost wedges appear at the top of the deposit while also, the cross bedded structure is reappearing again. A thin clay layer (3) (cf. Harelbeke) follows and is overlain by fine homogeneous sands wherein the post-glacial soil is developed. It is impossible to give an interpretation, whatsoever, to these uppermost sediments at present. It might be that they are to be classified within the *late coversands* series.

1.2.3.2. *The Sand Belt.*

Sint-Niklaas.

Thanks to the carefully drafted profile by Ing. M. GULINCK, made at the brickyard excavations of S.V.K. (Sint-Niklaas) in 1957 (fig. 20), the complete sequence of the quaternary deposits down to the top of the Boom clay is recorded.

The *loams and coarse sands* series start with a thin, coarse gravel layer (13) ravinating the Rupelian clay (14) and containing shark teeth, vertebrate reworked bones, shells, flint and quartz pebbles in great abundance. Next follow capricious sand lenses and bands (12), overlying almost immediately the gravel and are in turn overlain by a rather thick mass of sandy loam (11) within which clay pebble breccia (br) were noticed.

The series of *peaty loam formations* (10 to 6) are regularly developed in the right part of the section and extend very probably up to about 2 m, thus comprising M. GULINCK's description of alternating loams and capricious sand lenses recalling a ripple-mark structure. Oxydation horizons occur at the bottom of the sand lenses (cf. Rumbeke).

This deposit is followed by a gray *coverloam 1* with very fine stratification (4) and mottled at the base (5). From the top of this deposit, a *large frost wedge* (3) extends as far down as the Rupelian clay.

Above the *large frost wedge* (*row*) appears a yellowish mottled loose sand (2) (*coversand 2*) carrying the post-glacial soil at its top.

Mechelen (Schonenberg).

The present section (fig. 21) was temporarily exposed in a trench excavated for a sewage system at the locality Schonenberg (Mechelen.) Mr. S. GEETS (Ghent State University) was so kind to inform us about the works and to lead a field trip to the site.

The sequence begins with *loams and coarse sands* at the bottom. The lowermost deposit is a complex of alternating sand and loam (11) followed upwards by a series of three gray sand layers separated by two intercalated dark gray very fine stratified, loams beds (10). At the bottom of each sand layer, fine frost wedges and cryoturbation pockets occur. The whole is truncated along a sharp discordant junction line, coinciding with a *small frost wedge row* overlain by a discontinuous pebble band (*desert pavement 1*) (9).

The (*peaty*) *loam formations* are overlying the latter pebble band horizon and four levels can be distinguished. The lowermost is a brown loamy sand (8) with fluviatile ripple mark structure wherein numerous little, paralelly inclined frost wedges occur at different levels. This horizon is partly eroded by outspoken fluviatile fine sands (7) which is in turn truncated by a sharp junction line along which little frost wedges and cryoturbation pockets appear. Above follow again two brown loamy sand beds (6 and 5) similar to the lowermost, both bearing also little frost wedges and cryoturbation pockets at their respective upper limits. On the very upper one a pebble band may occur (4).

The *coversand 1* series is composed of quickly alternating sandy and loamy layers with numerous dispersed little frost wedges (3) and limited at the top by a *large frost wedge row* (2') composed of large frost wedges (1 m deep and 30 cm wide) and also large cryoturbation pockets (0.60 m deep and 50 cm wide).

This level is overlain by *coversand 2* (2) almost completely overshadowed by the textural-B-horizon of the post-glacial soil (1).

Hingene.

In this section (fig. 22) the deposits excell by their fluviatile character. The lowermost observable deposits are *sands and gravels* (8) overlain by a cold peat layer (R. VANHOORNE, kindly reported) inserted in a complex of *loams and coarse sands* (7). It is not clear wether the cold peat points to a *Zelzate* or *Warneton soil* age. On account of its litho-stratigraphical position it is more likely to consider a Warneton age for it. Above follows a series of cross bedded fine loamy sands with numerous peaty lenses (6). The latter recall a fluviatile facies of the *peaty loam formations*. A similar facies of the *peaty loam formations* was earlier recorded at Quesnoy (R. PAEPE, 1965) and at Kesselt (F. GULLENTOPS, 1954). They are limited at the top by a sharp junction line under which locally a faintly developed *cryoturbated soil horizon* was observed along the south side of the sandpit (not reproduced here).

Immediately above follows the *cross bedded sands series* (5) characterized by the absence of peaty formations and the occurrence of fine deepgoing frost wedges.

The *coversand* (composed of alternating sands and loamy sands) (4) overlying the sands are considered as *coversand 2*; for the junction line between the two formations may be affected by cryoturbatic involutions and frost wedges which should then occupy the position of the *large frost wedge row*.

Next follows a series of quickly alternating sand and loams (3), separated by a cryoturbation zone from overlying fine layered sands (2). Both deposits do not reflect the typical coversand facies and are hitherto referred to respectively as *late coversand 1* and *2*.

The whole sequence is covered by holocene peat. Notice that the entire coversand sequence is rather thin, a feature recorded also from other places in this area (e.a. Hoboken).

1.2.3.3. *The Scheldt Valley*.

The tunnel excavations for the E3-super highway section between Antwerp and Ghent, yielded long and deep profiles reaching the top of the tertiary substratum. Earlier F. HALET (1923) published the sections of the existing tunnels. The deposits are for the greater part entirely fluviatile and cryoturbatic phenomenas are often lacking completely (left bank). Their thicknesses are furthermore very reduced making correlations difficult.

Antwerp (West bank).

The Boom clay (14) in the immediate vicinity of the river Scheldt is deeply and stepwise eroded by the overlying Pleistocene deposits (section 1 and 2) (fig. 23 and 24). This thalweg is filled with grayish green calcareous fine cross bedded sands (11), with peaty threads and somewhat gravelly at its base (12); its upper part is mixed with loamy lenses, entirely leached and shows furthermore a different colouring (10) (section 3) (fig. 25): gray brown due to an enrichment in both iron and humus. The lower limit of this colouring is diffuse and does not tally with the boundaries between the cross bedded structures so that a pedological process is assumed for its origin. Actually, peat detritus of Eemian age (R. VANHOORNE, p. 67) filling up small gullies (fig. 26; bed 9), occur commonly in the upper zone of these series and belong most probably, chronologically speaking, to the vegetation that caused leaching and consequently the establishment of the gray brown horizon. Although the peat was definitely transported, its constant appearance in the aforementioned position permits the statement that this transport occurred rather comptemporaneously of the period which afforded its development. Therefore, both peat and soil are attributed to the Eemian period and together with the underlying deposits referred to as *peat and gravels.*

A series of *sands and gravels* (8*a*, 8*b* and 8*c*) rests discordantly on the Eem deposits (section 3). The lowermost layer (8*c*) is a coarse leached grayish sand and even white at its base. It shows the characteristics of an A_2-horizon, which in places has also affected the top of the underlying Eem deposits. In the latter cases, the irregular but sharp lower limit occurs at about 10 cm to 15 cm below the geological line of discordance between fine sands and overlying gravels.

Towards the top, an increase in humus may be noticed while also number of large fragments of unweathered Boom clay occur frequently but they form no obstacle whatsoever for considering this horizon as an A_2 (J. AMERYCKX) (*).

The corresponding B-horizon is characterized by a heavy red colouring giving proof of a high iron content and also of humus (*). This B_{ir}-horizon occurs at a rather constant level and may penetrate either in the very top zone of the underlying gray brown (Eemian) horizon, or may form a duricrust in the lower part of the leached sands, resting immediately on the fine Eemian sands or still, may occur as isolated patches within the bulk of the leached A_2-horizon. When occurring in the coarse sands the reddish colouring may show apophyses following the sedimentation structure.

From the above it may be stated that the gray brown horizon stands without any relation to the A_2-B_{ir} soil continuum, a fact that is also supported by the presence, although seldom, of fine featherlike frost wedges developing downwards from the junction line between the gravelly sands and the fine Eemian sands. At one place, a frost wedge started at the upper limit of a peaty gully just underneath the gravelly sands while in two other cases, they could only be followed from the base of the A_2-horizon developed in the fine sands (section 3). Probably soil homogenization overshadows their presence in the A_2-horizon up to the contact with the coarse sands.

In order to distinguish the A_2-B_{ir} soil continuum from the gray brown horizon, we have preconised the connotation *Antwerp soil* for it (photo 10).

The succession of the *sand and gravels* continues upwards with a very coarse, gravelly sand (8*b*) containing numerous threads of Fe/Mn, many rolled fragments of Boom clay, locally also lumps of reworked amorphous peat, and bone fragments. This bed ravinates the underlying coarse sand and is separated from the overlying yellowish fine gravelly sand (8*a*) by a subhorizontal, sharp discordance line (section 3).

Whereas the beds 8*b* and 8*c* happen to wedge out against the uprising Boom clay substratum (section 1 and 2), the yellowish sands (8*a*) may locally show a strong increase in thickness, attaining simultaneously a cross bedded structure. Finally they also thin out landinwards, outside the thalweg where they then come to rest directly on the uprising Boom clay substratum, too. In the latter position the gravel is composed of coarse sand, with sporadic flint fragments and many congelifractated fragments of septaria derived from the underlying Boom clay. Also shells (*Pisidium*, etc.), stems of *Chara* (R. VAN-

(*) Kindly reported.

HOORNE, p. 74) and fossil bones occur in great abundance while at one place, two lithic implements were found, one of which is certainly a Levalloisian side-scraper or point. Thanks to the presence of this tool showing a high degree of technique development, it was possible to classify the deposits within which they were found as of Weichsel in age. Of course we have no pretention, whatsoever, as to correlate this unique implement to a definite prehistoric phase.

From a geomorphological point of view, stress must be laid on the fact that the two steps along the thalweg slope on top of the Boom clay coincide with the upper limit of the fine gray sands underneath the gray brown horizon and the next one with the lower base of the zone with peaty gullies. So the steps were developed almost simultaneously with the sedimentation of the Eemian deposits (fig. 27).

Also the *sand and gravels*, even where they show cross bedded structures, seem not to belong to a river system capable to erode the underlying deposits strongly, contrary to the underlying deposits during which shaping of the thalweg proceeded.

Loams and coarse sands, composed of a basal gray peaty loam (7) with subsequently a sandy and a loamy layer (6) above it occur as a relatively thin deposit when resting on the thin gravel overlying the Boom clay (fig. 25). Towards the river Scheldt these series go over in a series of sandy and loamy layers locally with cross bedded structure while the basal peaty layer is wedging out (sections 1 and 2) (fig. 23 and 24).

Finally a dark peat horizon (5) (fig. 23 and 24) follows, also laterally tonguing out in three or four layers towards the Scheldt between the aforementioned series of alternating sand and loam beds. R. VANHOORNE revealed an early Weichselian age for these deposits (this volume, p. 72) while stratigraphically they correspond with the *Warneton soil* level.

The blue gray somewhat clayey sand (4) which usually follows above the peat, undergoes also important changes in texture towards the Scheldt. There, the upper part remains only sandy while the lower part becomes gradually a system of alternating sand and loam beds. Sometimes a pebble layer (3) is found on top of these deposits, overlying a thin veneer of peaty lenses or in places, a gley horizon. Although cryoturbatic disturbances are found nowhere at this level, the latter horizon tallies stratigraphically with the *cryoturbated soil horizon*. For the whole is covered by homogeneous blue gray compact sands (2) when wet, but yellowish and loose when dry. In the latter position they can easily be assimilated with a *coversand* formation.

A post-glacial podzolic soil occurs in the upper part of the *coversands* buried under a constant layer of holocene peat (1).

Hoboken (East bank).

The profile of the almost 1 km long train tunnel pit (fig. 28, east bank) permits observations dealing with the transition between the pleistocene stratigraphic sequences nearby the Scheldt (similar to the ones described above on the west bank) and the ones occurring further landinwards.

The Boom clay (14) is found at about the same topographic level as on the west bank. Its surface, however, is slightly doming towards the Scheldt but lowers smoothly to the east. In the doming area, the clay is also affected by « diapir » structures (P. LAGA, 1965), pearcing through a 3 m thick miocene fine sand deposit (13) into the base of the pleistocene base gravel beds (12).

In order to understand the succession and lateral variations of the pleistocene deposits, we first comment a detail section recorded at the entrance of the train tunnel pit (fig. 29).

The *sands and gravels*, eroding the miocene sands, are composed of basal medium fine cross bedded sands (12) containing a lot of vertebrate bones evolving upwards into a rich (reworked) shellbearing, also cross bedded, gravel deposit.

Hereupon, along a tonguing junction line, lies a greenish, fine sand with outspoken ripplemark structure (11), sometimes devided into two parts by a fine gravelly layer. To the west, these sands become gray brown in colour and finally a reddish horizon (10) is developed at its top.

The latter is overlain by gullies with detritus peat (9) so that the picture of the Eemian *peat and gravels* deposits with infiltration of the *Antwerp soil* in its top zone is found back here.

A fine pebble band (*desert pavement 1*) underlain by a sporadically occurring *small frost wedge row*, truncates the *sand and gravels* almost horizontally. In places this pebble band develops laterally into a real fine fluviatile gravel bed (8), intermingled then with reworked shells from the underlying Tertiary and becomes the constant facies towards the west end of the section. As the horizontal junction line formed by *desert pavement 1* continues uninterruptedly above the thicker gravel beds one is justified to conclude that the pebble band originated from the erosion of previously deposited fluviatile gravels.

The next overlying deposits are the *peaty loam formations* (4) composed at their base of alternating pale sands and dark humic loam layers terminating with a first cryoturbated soil horizon overlain by a row of frost wedges. Sometimes only lenses of it, which underwent fluviatile transport, are found. The level, called *Hoboken soil* was dated 32,490 ± 440 y.B.P. (Gr. N-4781); the sample was taken in another section: section 7, bed 4 (fig. 28 and 30; photo 12).

Above it, the *peaty loam formations* continue with a fine green sand, probably partly eolian in origin, underlying another series of alternating pale sands and loams. At the base of the latter frost wedges may occur too. Next follows another green fine (eolian) sand becoming coarser and locally more clayey to the top and also containing many fine plant remains and gley mottles. It is affected by cryoturbatic structures and overlain by a row of sporadically appearing frost wedge.

The latter horizon is the *cryoturbated soil horizon* as it is overlain by a yellowish eolian *coversand 2* from which it is separated by a continuous well developed pebble band (*desert pavement 3*) (3). The post-glacial podzol soil is developed in these sands, so that according to what was stated above, they cannot be anything else but *coversand 2*.

At the very west end, the whole is ravinated by holocene deposits.

The just described sequence is the normal one, especially when considering the typical facies of the *peaty loam formations*. If we now follow this type sequence towards the Scheldt (fig. 28), we then see the following evolution.

The *sands and gravels* follow first the doming of the underlying Boom clay and drop consecutively rapidly towards the Scheldt waterfront. Nevertheless, they remain still 3 m higher than the top of the Eemian deposits on the west bank. The reddish soil has disappeared and only the brownish facies of the fine sand and the shell-bearing gravels are conservated.

The *peaty loam formations* (4) undergo also important lateral changes, in that the cryoturbation and frost wedge horizon disappear completely as well as the peat bearing loam layers themselves. Finally the entire formation has made room for the same blue gray sand carrying a gleyified horizon with plant remains at its top. Here also, *desert pavement 3* (3) is found on top of these sands and overlain by the *coversand 2* (2) deposits with the post-glacial soil, the whole covered by holocene peat.

Towards the east, more landinwards, the normal sequence differs from the one at the train tunnel entrance only in that the cryoturbation features become more strongly developed and more abundant (fig. 30; photo 12).

1.3. THE CHRONO-STRATIGRAPHICAL AND CLIMATOLOGICAL SIGNIFICANCE OF THE PERIGLACIAL PHENOMENA AND THEIR GEOMORPHOLOGICAL IMPLICATIONS.

Frost wedges, cryoturbatic involutions, solifluction deposits and stone lines (desert pavements) are common features of the periglacial deposits. Their seemingly irregular occurrence has made it, up to very recently, difficult to attribute a real stratigraphical meaning to them. In the past ten years, however, thanks to observations in Central Europe (G. SELZER 1936, E. SCHÖNHALS 1951, J. FRECHEN and E. ROSAUER 1959, H. ROHDENBURG 1966) and in Western Europe (K. BRUN-

NACKER 1957, T. VAN DER HAMMEN, G. MAARLEVELD, W.K. ZAGWIJN and J.C. VOGEL 1967, R. PAEPE 1963) the chronological significance of frost wedge levels as stratigraphical bench marks, especially of the Weichsel has been generally accepted. Also the increasing knowledge on the genesis of frost wedges yielded from areas with present-day frost activity (Alaska, Siberia and Antarctica), has helped a lot on understanding their appearance, absence, morphology, size and frequency with respect to the climatological and sedimentological conditions which controlled their formation. This is particularly true for those periglacial phenomena occurring on a row along the junction line of major lithological units. Contrary to solely occurring features, due to local climatic conditions and prevailing temporarily only during the sedimentation of a particular bed, the in-a-row established phenomena are the result of ubiquitous changes of the palaeoclimatic conditions, characterizing and causing the major breaks of the lithological sequences. As of then, they deserve a chrono-stratigraphical and climatological position within a stratigraphical sequence.

1.3.1. FROST WEDGES.

Eversince the pioneer work of E. LEFFINGWELL (1915) on the origin of ground ice wedges, frost wedges are no longer believed to be the result of ice wedge formation only; they can also be produced by periodic contraction due solely to dessication and repeated filling with sand or loam in the perennially frozen ground. Such wedges are then called «sand wedges» and the related polygons «tessalations» (T.L. PÉWÉ, 1959). Similar connotations are found in earlier European literature such as: «Lösskeile» (J. BÜDEL, 1959), «Lehmkeile» (G. SELZER, 1936), «fentes à remplissage» (P. MACAR and W. VAN LECWIJCK, 1958) to indicate frost-like structures filled with clastic material. It now looks as if the origin of both types of wedges are similar: cracks produced by the great change in temperature from summer to winter; repeated cracking and filling with ice or sand, occasionally loam («Lehmkeil»), result in wedge-shaped fillings (T. L. PÉWÉ, 1959, P. A. SHUMSKY, al. 1955; J. BÜDEL, 1959).

Although the presence of fossil frost wedges provides evidence of cold-dry palaeoclimatic conditions (J. DYLIK, 1966) it is none the less also bounded to a certain degree of humidity of the soil causing accelerated contraction and delatation of the ground. This may explain why in extreme dry, continental conditions, frost wedges happen to occur rather scarcely (T.L. PÉWÉ, 1965). SHUMSKIJ et al. (1955) hold the same view for coarse textured sediments, stating that frost wedges are formed there only at very low temperature. Humid and fine grained deposits are most favourable for frost wedge development. A flat, periodically submerged terrace is the best topographical position.

The perenne tjäle, which is the *conditio sine qua non* for frost wedge formation can also be a limiting factor for their downwards extension. Again SHUMSKIJ et al. (1955) points out that the penetration depth of synchronous frost wedges is the same and limited by the upper limit of the permafrost (pergelisol table) (K. BRYAN, 1946, 1951). This depth limit is 20-30 cm in the northern tundra and 2-3 m in the more northernly regions of Siberia.

If such forms are then buried under a frost protecting cover, the growth of the frost wedges stops even when a new frost wedge cycle develops later above it.

But it may occur that severe climatic conditions prevail and that growth of initial frost wedges goes on over a long lapse of geological time. This happens when the frost wedge, remains open nothwithstanding the menace for slump with the rise of temperature during the following summer or any warmer phase. Frost wedge deepening occurs then far beneath the pergelisol table (SHUMSKIJ et al. 1955, T.L. PÉWÉ, 1959) while also a widening of the frost wedge is observed (T.L. PÉWÉ, 1959). The rate of increase of width at the top is estimated at 0,5-1 m for about one thousand years (BLACK and BERG, 1963).

J. BÜDEL (1959) and J. CZERWINSKI (1964) hold that such frost wedges, may undergo changes into pocketlike or pearlike forms as a result of lateral pressure becoming stronger in the bottom part of the wedge than in the neighbouring substratum.

According to the above, J. BÜDEL (1959) pointed out that climatic fluctuations, occurring at the transition of cold to warm periods or vice versa i.e. at the end or at the beginning of an interglacial or interstadial, are favourable conditions for frost wedge growth.

It may happen that frost wedges develop in earlier formed, underlying frost wedges which are actually weak spots for repeated cracking (P.A. SHUMSKIJ et al, 1955). This results in a kind of « cone in cone » superposition of frost wedges.

In the aforementioned, it was tacitly understood that the frost wedges were formed after deposition of the sediment. The latter type of frost wedges are called *epigenetic* (H. GALLWITS, 1949). If, however, frost wedges develop and elongate simultaneously with the increase in accumulation of the sediment cover, than they are called *syngenetic*. Syngenetic frost wedges may be very deeply developed and still remain narrow. Also, due to their simultaneous growth with the sediment thickness, the subparallel wedgelike filling layers start along the wedge-limit instead of at the upper top limit (P.A. SHUMSKIJ, 1955). This distinction is important when dealing with the « cone in cone » superposition of epigenetic frost wedges.

Contrary to what happens under epigenetic development, permafrost is shifting upwards as a result of progressive accumulation, and consequently, also the fissure development. This is at the expense of the growth in width (J. DYLIK, 1966).

The most striking aspect in the by us observed syngenetic frost wedge is its featherlike structure. We found however featherlike, apparently syngenetic frost wedges cutting several beds of cross bedded deposits (cf. Hingene). It is very unlikely that such structures developed simultaneously with the sedimentation of the deposits.

J. DYLIK (1966) pointed out that the topographic (environmental) situation of a given polygon is an indication facilitating a distinction between epigenetic and syngenetic structures. This author states that syngenetic development could easily proceed on sea shores, in river valleys, lake basins and denudation valleys or on alluvial fans. In all other places, the polygons (with the exception of tessalations) may have undergone epigenetic development.

According to this, the occurrence of one or another frost wedge does not give proof of the prevailing general climatic conditions whatsoever. Hence, both types may be found at any level of the stratigraphy, a statement which is in complete accordance with our observations.

Polygons occur as rectangular patterns in homogeneous material e.g. river-flood terraces. B.N. DOSTOVALOV (1952, 1960) (in J. DYLIK, 1966) ascribes development of such polygons as due to repeated recurrence of the first order cycle (the largest polygons) by cracking of frozen ground into minor, lower order cycles. J. DYLIK (1966) states furthermore that the milder the climate, the larger the polygons.

The frequency of frost wedges, exposed along a wall of exposure, permits calculation of the dimension of the corresponding polygonal net. J.S. GOZDZIK (1964) estimates that on multiplying the average distance between the frost wedges by a factor 1,1 the dimension of a polygonal net is obtained.

Small polygons (1,5 — 3,0 m) have been reported as dessication phenomena (A. JAHN, 1950) although larger seem to exist too, i.e. in New Mexico (100 m and more) (*).

1.3.2. INTERPRETATION OF THE FROST WEDGE LEVELS.

From the aforementioned profile description it follows that three, main levels of frost wedges are commonly recognized within the Weichselian, periglacial deposits of Belgium.

1.3.2.1. *Small Frost Wedge Row.*

The lowermost or *small frost wedge row* lies either above the *Warneton soil* or on top of the *loams and coarse sands* and is in turn overlain by *desert pavement 1* or /and the *Poperinge soil* if present.

(*) This was kindly reported to us by Prof. Dr. R.V. RUHE (I.S.U. Ames, Iowa).

Its occurrence seems preferably bounded to widespread flat, horizontal topographies build up by fluviatile deposits (Warneton, Racour, Maisières, Zonnebeke) of large river valley systems or to fluvial-solifluction deposits (Tongrinne, Volkegem) on plateau's. Poor development is observed in fillings restricted to shallow valleys with concave slopes (Poperinge, Rumbeke, Mechelen) where sedimentation took place seemingly in a more disorderly manner if compared with the afore mentioned sites. They are, however, completely lacking in river deposits giving proof of a permanent high water table (Antwerp). As a result, it may be stated then, that its size and frequency is depending on strictly environmental conditions.

For this is even true within the limits of one profile section. At Warneton, they are generally tall (1 m in depth) and thin (max. 5 cm), revealing a syngenetic development on deposits, whereas on thinner, more loess fluviatile like deposits their form reveals an epigenetic origin and a decrease in depth (20 — 30 cm) and an increase in width (15 cm) can be noticed. Within each reach of development, depth limit was the same conjecturing that also permafrost was a locally bounded phenomenon.

Wet conditions also have undoubtedly favourised the establishment of the *small frost wedge row*. Besides Warneton, comparison of Tongrinne with Racour (both situated in the loam belt) leads to the conclusion that drought only influenced the size of the frost wedges positively (Tongrinne) whilst humidity its frequency (Racour).

It is also noteworthy that, although generally, only one row of *small frost wedges* is present, it may also be found (Warneton and Racour, in the worst drainage conditions!) at the end of a series of superposed discontinuous frost wedge levels. This implies that climatically the *small frost wedges row* is a result of a gradual evolution of frost wedge development of which probably the relatively most severe and last impression, has been preserved. In the meanwhile, it can also be deducted that there was no continuity as to persistance of i.e. low temperature from one level to another for then frost wedge growth would have been possible beneath the limit of the permafrost. This statement is also in agreement with the fact that at Warneton, the horizontal development of the *small frost wedge row* was found to build up a rectangular pattern.

It is our conviction now that the climatical oscillation responsable for the *small frost wedge row* s.s. was a relatively mild and short one the effect of which was only recorded when appropriate topographical-lithological conditions were present. It was, however, more severe and of more widespread character than all the previous attempts in this direction.

1.3.2.2. *Large Frost Wedge Row.*

The uppermost or *large frost wedge row* occurs at the base of the *coverloam 2* or *coversand 2*, commonly overlain by *desert pavement 3* and is often overlying a zone of cryoturbatic undulations at the top of *coverloam 1*. It may also rest directly on the *cryoturbated soil horizon*.

Contrary to the former frost wedge zone, this one does not fail to exist very often and furthermore appears commonly as a row of deep and wide wedges, V-shaped and alternating with pocketlike or pearlike forms, established along a sharp subhorizontal junction line. Usually the wedges are filled with material from the overlying coversands if epigenetic (Tongrinne, Rumbeke, Poperinge, Zonnebeke); sometimes only syngenetic wedges (Esquelmes, Zelzate) are present.

Whatever the kind of wedge which is dealt with, they usually appear at a high frequency (1 per m) and with rather constant penetration depth in broad river valleys (Warneton, Ploegsteert, Zelzate, Ghent, Esquelmes, Mechelen), or on slopes (Rumbeke, Racour). On extreme plateau position (Tongrinne, Poperinge), however, their occurrence may be very scarce, but at the same time, they attain a greater depth and width (respectively 3 — 5 m and 1 m and more). Once again, it follows that, given certain climatic conditions, places with high moisture saturation of the soil are favourising a high frequency of frost wedge (polygon) development even though they are a limiting factor for penetration depth (constant) and thus also for frost wedge growth.

This may yield a false image of the prevailing climatical conditions. For, the large, deepgoing frost wedges and pocketlike forms are witnessing of the existence of number of cycles of activity on one and the same frost wedge, remaining open over a long period of time. This is the major existing difference between the *small* and *large frost wedge row*.

As a consequence, we think that during formation of the *large frost wedge row*, the climate was much more severe, with other words colder and dryer than during the period of the *small frost wedge* formations, and probably also of longer duration.

Another conclusion follows directly from the above: the *large frost wedge row* represents an important hiatus in the sedimentation cycle of the coversands. Actually, as has been observed at Poperinge, the coversands intercalated between two openings of superimposed large frost wedges laterally develop into an important series of *cross bedded sands* and *coversands*.

1.3.2.3. *Fine Frost Wedge Row.*

In between the above described frost wedge levels exists locally another more weakly developed one composed of *fine frost wedges* (Wevelgem, Warneton). Usually, it forms part of a cryoturbation level just below the *cross bedded sands*, *coversand 1* or *coverloam 1* series and may be very restricted in extension.

We come back to this point in next section.

1.3.2.4. *Sporadical Frost Wedges.*

Sporadically, frost wedges may appear abundantly inside the series of the *peaty loam formations*, the *cross bedded sands* and the *coverloams* or *coversands*. They may or may not be aligned in a row **and** therefore are of a minor stratigraphical importance. They are, however, a morpho-stratigraphic characteristic of the deposit to which they belong.

In the *peaty loam formations* they usually are syngenetic and very small in size. It looks as if the time considered with their development was short and they could not survive the decay of the climatic conditions which induced their existence.

Syngenetic frost wedges were observed in a orderly arrangement at the contact between Weichselian and Eemian deposits at Hoboken and Antwerp (West Bank). Their frequency, is extremely low and in many places only some frost wedgelike disturbances (i.e. Warneton, Poperinge, Tongrinne) were found.

1.3.3. Cryoturbatic Involutions and Solifluction Deposits.

Another striking feature of the periglacial area, if not the most important, is the presence of cryoturbatic involutions. They occur in the same « active layer » (S.W. Muller, 1945) just above the perenne tjäle (although they may also be produced above solid bedrock) within which frost wedges are produced. A microcryoturbation level marks in places the pergelisol-table and is then composed of dropping structures (« druipstaarten », « Lehmtropfen »), (V. Steusloff, 1952). It is however worth saying that J. Czerwinski and A. Jahn (1965) noticed formation of droppings in the processes of sedimentation due to load cast whereas other droppings solely originated under influence of the frost impetus.

The softening of the active layer is the major characteristic of the cryoturbation process and sets in motion the forces which result in *congeliturbation* (K. Bryan, 1946). Hence the congeliturbate is composed of disturbed material (warp, trail, head, « Brödelerde », « Erdfliessen ») including also solifluction (K. Bryan, 1946). J. Büdel (1959) called attention to the existing relationship between solifluction and cryoturbation and based their distinction on the presence or absence of gravitational forces depending on the degree of slope (respectively more or less than 2 °). By doing this he re-established the original meaning of solifluction as defined by Andersson (1906) and later by Högbom (1914). Furthermore, C. Troll (1944, 1957) and subsequently J. Büdel (1959) set forth that various types of frost-climates induce various types of cryoturbation and solifluction.

J. Büdel (1959) has clear-cut ideas on these matters. Besides the already made distinction between cryoturbation and solifluction, he introduced a subdivision in the type of solifluction.

The general type of solifluction is the one occurring, even in present-day periglacial areas (Spitsberg), on slopes exceeding 4 °-6 ° with a variable maximum of 17 °-27 °. He contributes this kind of so-called normal solifluction to a periodically, continuous flow dating of the snowmelt period at the beginning of the Summer. Such *periodic solifluction* sheets, even when fossilised, occur as fresh looking surface deposits. Due to the mulching of the material, no frost phenomena are preserved in it.

In periglacial Central Europe, on slopes with less than 4 °-6 ° inclination, another type of solifluction can be observed. Contrary to the above mentioned one, it is called *episodic solifluction* for it does occur only episodically. It is bounded to an abnormal high degree of water saturation in the active layer, which conditions were only available during the shortened melt water period of the Last Glacial (J. Büdel, 1959). All frost structures are preserved in such episodic solifluction deposits. Hence they are, as is clearly stated by J. Büdel, the transitional form from cryoturbation layers towards periodic solifluction deposits on steeper slopes. Therefore they rank amongst the important denudation processes of the cold Pleistocene epoch.

Furthermore, thickness and depth of the episodic solifluction is dependant on the degree of slope exposure and lithology which variables also influence the depth of thawing.

1.3.4. Interpretation of the Cryoturbation-Solifluction Levels.

1.3.4.1. *Cryoturbated Soil Horizon.*

In between the above mentioned frost wedge levels, two distinct cryoturbation horizons generally occur: one of them coincides with the top of the *peaty loam formations*, another one is developed within the bulk or at the top of the *coverloam 1* or *coversand 1*.

From a stratigraphical point of view, the so-called *cryoturbated soil horizon* (Zelzate-Kesselt horizon) on top of the *peaty loam formations* is the most important one. Its strongest development occurs when overlying a solifluction layer (e.g. Zelzate, Tongrinne), while on fluvial deposits it rather makes room for frost wedge development (e.g. Wevelgem, Harelbeke, Poperinge, Warneton, Hoboken, Mechelen).

Sometimes, a second, similar cryoturbation layer is found below the first mentioned (Hoboken, Rumbeke) affecting then the *Hoboken soil.* This horizon never attains the degree of development and constancy of the *cryoturbated soil horizon* even when its development is stronger than other sporadically appearing cryoturbatic structures in the lower part of the *peaty loam formations.*

So it can be stated that the uppermost cryoturbation level is by and large the strongest and most widespread feature of a common process of the *peaty loam formations.* In other words, environmental conditions were most favourable at this level for its appearance. They are probably due to a longer period of a standstill between two cycles of sedimentation inducing a deeper thaw and freeze effect and thus also a greater thickness of the active layer.

It goes without saying that such important general changes in the environmental conditions are the result of climatical changes of world wide emphasis.

1.3.4.2. *Cryoturbation Level of the Coversand 1 or Coverloam 1.*

The next important cryoturbatic level is the one occurring in the middle of the *coversand 1* deposits (Zelzate). W.H. Zagwijn, on a field excursion kindly drew our attention to its widespread presence in the so-called *older coversand 1* of the Netherlands (see also T. van der Hammen et al., 1967). But in the latter country it underlies immediately the *large frost wedge row* with *desert pavement 3* (called there *Beuningen Gravel Bed*). A similar situation is found in the south-western part of the Flanders, where cryoturbatic undulations are usually occurring directly underneath the *large frost wedge row* (Warneton, Rumbeke etc.) in the *coversand 1* or *coverloam 1* deposits.

So it can be stated that two generations of frost activity follow quickly one on the other and that usually there happens to exist a lithostratigraphical hiatus between them.

Such sequence of two generations was also reported by M. PECSI (1964) from profile sections along the Danube and his profile drawings entirely tally with our observations.

Hence the cryoturbatic level of the *coverloam 1* or *coversand 1* ranks fully as an independent stratigraphic level. According to this, one is justified to classify the loam deposits with undulations in the upper part as *coverloam 1* even when the *large frost wedge row* is lacking above them.

This cryoturbation horizon and the one affecting the *cryoturbated soil horizon* are furthermore accompanied by sedimentation structures similar to the ones that were accounted for by J. BÜDEL, as episodic solifluction.

1.3.4.3. *Solifluction Structures of the Loams and Coarse Sands.*

Episodic solifluction is the dominating characteristic of the *loams and coarse sands* but here too bound cryoturbations, as we have seen, may still affect the solifluction mass, especially its upper part.

1.3.4.4. *Solifluction Structures of the (Peaty) Loam Formations.*

A special type of solifluction is yielded from the regularly stratified *loam formations* of Tongrinne and of Zelzate (bed 15) and also from the *peaty loam formations* of other sites. They deserve special attention for their specific pattern makes it easy to recognize them in the field as a diagnostic horizon.

There are first the *loam formations* which, as described above, are composed of thin regularly disposed quickly alternating layers of finer and coarser textures with numerous, paralelly inclined fine frost wedges and microfestoonlike irregularities along the upper boundary of the loamy layers. Such structure pattern portrays a succession of fine solifluction layers deposited rather rapidly in a short lapse of time, very similar to a varve sedimentation. For the regularity of the superposed thin strata together with the presence and smallness of the frost wedges, implying (subaerial) frost activity of short duration, lead to the conclusion that the solifluction processes occurred periodically and were limited in depth too.

In the *peaty loam formations*, fluvial deposits interfere with the (humic) solifluction layers (Ghent, Poperinge, Rumbeke, Warneton, Hoboken, Harelbeke) and may even become the dominant characteristic of the deposit. But even then, the quick succession of fine layers remains a most striking feature thus giving proof of a widespread, constant sedimentation phenomenon.

From the afore, it can be stated that between the periods of the *small frost wedge row* and the *cryoturbated soil horizon* formation, periodic solifluction and its according sheet erosion was the overwhole process. They cannot but have been controlled by world wide prevailing climatic conditions characterized by quick (periodical, seasonal) oscillations of relatively cold-wet and cold-dry conditions.

It must be noticed here that the solifluction deposits as mapped by R. MARÉCHAL (1955) are generally confined to superficial deposits, occasionnally overlain by a thin loam or sand layer. Later, the same author (1956) extends the occurrence of solifluction deposits also to the lower lying loess deposits and bases his statement on personal observations as well as those yielded by F. GULLENTOPS (1952, 1954), P. DE BETHUNE (1951) and G. SCHEYS (1955).

Although it is generally accepted that the loamy solifluction deposits were closely related to the loess deposits, no further major climatical stratigraphical significance was earlier assigned to them.

1.3.5. DESERT PAVEMENTS.

1.3.5.1. *Pebble Bands, Prêles, Stone Lines, Desert Pavements or Pediment Deposits.*

From our descriptions it follows that three levels of pebble bands or stone lines happen to occur in the Pleniglacial deposits. Earlier

R. TAVERNIER (1945) mentioned the existence of two such horizons at Aalter (coversand area) while R. MARÉCHAL (1956) has stated that such levels may occur both in the upperlying cover deposits and in the underlying solifluction loams.

As they are usually composed of a thin row of eolised pebbles they were believed to be « deflation zones » (C. EDELMAN and R. TAVERNIER, 1940; R. TAVERNIER and A. HACQUAERT, 1940) dating from the Pleniglacial periods.

R.V. RUHE (1954, 1956, 1958) called attention to the existing resemblance between « pebble bands » found in Pleistocene deposits of the mid-continent of North America, the « stone lines » of Central Africa (Congo) and the so-called « desert pavements ». According to this author, « stone lines build up surfaces of large areal extend which are believed to be due most often to erosion by running water and the subsequent mantling of a lag or transported gravel by finer textured sediments ». The thus evolved erosion surface is a pediment.

R. TAVERNIER (1948) suggested earlier the term « pediment deposits » for the pebble bands observed in the loess deposits of Belgium, although in later publications (1954, 1957) he uses the term « prêles ».

1.3.5.2. *Areal Extent of the Desert Pavements.*

The large areal extent of the stone lines has been mapped in different parts of the transitional area (R. PAEPE, 1959; R. PAEPE and A. LOUIS, 1961). It was clearly shown that the nearer the top of the tertiary humps, the coarser the elements of the stone line. Furthermore, two stone lines can generally be followed as a thin veneer of gravelly sand over more than 5 km distance terminating in lensshaped accumulations, when debouching into a water course or/and when wedging out against a tertiary hump. From their large extension and high content of tertiary reworked elements, it was concluded as to their high mobility in the nature of transport.

1.3.5.3. *Characteristics of the Desert Pavements.*

The hereunder cited stone lines show the following common characteristics:

— they are composed of a fine eolised gravel, mixed with an eolian, fine sandy matrix although occasionnally fluviatile structures are also present;

— they truncate along a flat, subhorizontally displayed discordance line the underlying deposits;

— they are usually underlain by a frost wedge row or/and a cryoturbatic horizon.

From the afore mentioned, one may conclude to the following important statement in that the climatical changes involved with the installment of the stone lines, were less sudden than is conjectured by the sharp boundery which they are portraying. Actually their appearance goes along with a gradual fluctuation of the climate from cold-wet to cold-dry conditions. For the presence of fluviatile structures within stone line deposits has sufficiently been stressed, so that in agreement with observations yielded from other areas, we do believe that running water played an important role in the erosion and shaping of the pediment surface and its subsequent mantling with a pedi-sediment.

The question than rises why under the existing cold conditions solifluction had disappeared in favour of a pediplanation. A continuous, extreme high position of the permafrost may be assumed as a result of which fargoing, frost controlled desintegration of rocks and periodical, subsequent fluvial (meltwater) transport was limited to a thin veneer of the very upper part of the landsurface. The moreover constancy of undeep permafrost depth adds to the fixation of newly accumulated lag so that here also erosion affects only a thin veneer of the upper part of the deposit. Both processes finally result in a smooth plain. It may next be noticed that drought under polar desert conditions is at least partly due to the fixation and mineralisation of the water instead of the complete lack of it nearby the landsurface as is the case in subtropical deserts. After the building up of the smooth plain eolian activity becomes a dominant process as a result of increased severe cold-dry climatic conditions. Polishing of the pedi-sediment pebbles and important deflation is then the dominant process so that stone lines also imply, besides a climatic gradual fluctuation, an important stratigraphical hiatus.

Along with the decay of the climate, frost wedges formed after the establishment of the smooth surface. Indeed they are found along a continuous horizontal row and before or at the beginning of the eolian phase since eolised pebbles are found within the frost wedge body.

1.3.6. Interpretation of the Desert Pavement Levels.

1.3.6.1. *Desert Pavement 3.*

The uppermost stone-line level (*desert pavement 3*) is usually found above the *large frost wedge row* overlain by either *coverloam 2* or *coversand 2.* Its fluvial origin is set forth by the observation at Poperinge, showing a pebble band laterally going over into thick, gravelly *cross bedded sands.* This phenomenon was also reported from the Netherlands and was referred to as *Beuningen Gravel Bed* (T. van der Hammen et al., 1967).

Its constancy of appearance on widely varying deposits of different areas leads to the conclusion that its formation was controlled by world-wide prevailing climatical conditions of such intensity that they overwhelmed local conditions and were certainly not bounded to them. From the afore it may also be assumed that such conditions remained stable over a long lapse of time implying the persistence of a climatic high.

1.3.6.2. *Desert Pavement 1.*

The next important stone line (*desert pavement 1*) overlying the *small frost wedge row* and/or intercalated between the underlying *loams and coarse sands* and overlying *peaty loam formations,* does not show the same constancy as the former one.

Its distribution is restricted to places with favourable disposition for pedimentation e.g. fluvial terraces (Warneton, Hoboken, Racour). Also here lateral transition into more gravelly fluviatile deposits has been observed (Racour, Hoboken). It can therefore be stated that cold-dry conditions had not such an overwhole character as the ones existing during the development of *desert pavement 3.* Furthermore, this horizon can be completely absorbed in an overlying solifluction-fluvial deposit.

1.3.6.3. *Desert Pavement 2.*

Finally *desert pavement 2* occurs either occasionally on top of the *cryoturbated soil horizon* or of the *peaty loam formations* (Warneton, Rumbeke, Hoboken). It is extremely difficult to distinguish when overlain by *cross bedded sand* deposits. Conditions for pedimentation are believed to have been less favourable than for both the other ones and even more strongly controlled by local environmental predispositions than for *desert pavement 1.* Therefore the climatic oscillation which stands at the origin of it is believed to have been of relatively short duration.

1.4. PALAEOSOILS.

1.4.1. Stratigraphical Significance.

Since the palaeosoil is a soil that formed on a landscape of the past (R.V. Ruhe, 1965), it is a useful stratigraphic tool for recognition and determination of palaeoclimatic units. As the recent soils, the palaeosoils show great variations because of different relief, parent material and climate (J. Fink, 1965). If one finds palaeosoils that are analogues of the recent land-surface soils they may be similarly interpreted (J. Fink, 1965, R.V. Ruhe, 1965). But palaeosoils which are analogues of modern land-surface soils do not always occur in the same area. This, already, is an indication that the regional extent of palaeoclimatic conditions do not fully tally with those of to-day. Therefore, as for the lithologic composition and the periglacial features, a facies differentiation of the paleosoils is most desirable (J. Fink, 1962).

The more over, one may deal with palaeosoils of which no analogues are found to-day (J. Fink, 1956). Also, as clearly stated by R.V. Ruhe (1965), in the past palaeosoils have been confused with weathering profiles. The latter is a geological feature which, if not stripped off by erosion, may carry a palaeosoil in the uppermost zone.

Moreover, it is our conviction, that the study of palaeosoils is not possible without taking into account the litho-stratigraphical and geomorphological context. On the latter basis, it is possible to localize and recognize a new type of palaeosoil which otherwise would have been difficult to interpret.

Another, favourable aspect of the palaeosoils is the fact that they often permit absolute dating especially when humic or peaty. Relative dating is afforded by the study of the pollen accumulated in such horizons and also important conclusions on the environmental conditions are yielded (see R. VANHOORNE). Distinction of different groups of soil horizons with major palaeoclimatic implications is based on these criteria.

1.4.2. INTERPRETATION OF THE PALAEOSOIL HORIZONS.

1.4.2.1. *Rocourt Soil.*

F. GULLENTOPS (1954, 1957) introduced this term for an intensively, reddish coloured, truncated palaeosoil characterized by a strong development of an argillic horizon (textural-B-horizon, B_2t) with common irregularly displayed threads of red clay, exposed in the brick yard of Rocourt (Liège).

This facies of the *Rocourt soil* occurs frequently and with a great constancy at the top of the so-called older loess deposits in the loess area. No analogues of it were found among the present land-surface soils of Belgium and an interglacial, Eemian age was attributed to it on basis of its high degree of chemical weathering. This interpretation is also found correct at the marvellous section of Tongrinne, where R. PAEPE (1966) showed clearly that no major stratigraphical hiatus occurs between true the truncated reddish soil horizon and the overlying deposits. Indeed, it may be assumed that little erosion ever affected the top of Meuse-Scheldt divide upon which the Tongrinne site is located. This assumption is supported in the field by the fact that the only evidence of erosion of the (truncated) *Rocourt soil* is the undeep ravinating, slightly gullying, contact of overlying solifluction deposits.

Outside the loess area, this soil shows similar pedo-geological relationships with the overlying deposits. In the transitional area (Warneton, Poperinge, Ploegsteert), however, the reddish facies is overshadowed by a great abundance of Fe/Mn concretions and gley mottles. It then recalls the *pseudogley* buildings, also dating from the last interglacial, in Austria (J. FINK, 1961) and Yougoslavia (Gj. JANEKOVIC, 1964).

In slightly higher topographic positions of the same profiles, the soil gains the typical aspect of the *Rocourt soil* again, while when going over into depressions (even when shallow) a highly gleyified, hydromorphic, blue greenish compact clay horizon appears.

The most important feature, however, is yielded from the coversand area where the reddish clayey horizon appears only sporadically e.a. at Zelzate. Here the stratigraphical Eemian position of the *Rocourt soil* could be assured. For, as we already saw, it occurs as a lateral facies of the Eemian gravel deposits with *Tapes senescens*. Also, the overlying litho-stratigraphical sequences are so similar to those of the loess area and the transitional area that it is beyond any doubt that the interglacial soil of Zelzate is not the *Rocourt soil* of other places.

The gray brown horizon of a podzollike soil, observed in the Scheldt valley is very likely the counterpart of the *Rocourt soil* developed on a fluviatile gravelly facies. For it is underlying peaty deposits of the same period which, as the soil horizon, are truncated by one and the same line of discordance. Such a gray brown horizon was also observed at Bury in a similar stratigraphic position (R. PAEPE, unpublished).

1.4.2.2. *Antwerp Soil.*

The so-called *Antwerp soil* which developed partly in the gray brown horizon and partly in the overlying gravels shows a striking A_2-B_2ir continuum. Assumingly this soil dates from the very beginning of the Weichsel for frost wedges are found just beneath it and commonly it starts to develop from above the Eemian peat gullies with which it does not show any relationship whatsoever.

Up to now, this is the most acceptable assumption, while no palynological data neither to deny nor to affirm, were obtained from the deposits carrying the *Antwerp soil*. It could be, however, that here we also deal with a Late Eemian soil formation, separated from the bulk of the Eem period by a cold oscillation. Indeed the peat corresponding with the *Warneton soil* horizon is found stratigraphically quite high above the *Antwerp soil*. This also is the reason why the present author introduced a new name for this pedological formation.

The morphology of the *Antwerp soil* reveals a podzollike horizon known from the tropics. The lack of clay in the spodic horizon does not allow one to correlate it with a red-yellow podzolic formation (O. VAN WAMBEKE and J. AMERIJCKX) (*). F. GULLENTOPS (*) attributed the B_{ir}-horizon solely to the effect of groundwater and then excluded a pedological weathering. We admit that groundwater has played a role but without excluding a process of podzolisation.

1.4.2.3. *Warneton Soil.*

R. PAEPE (1963, 1965, 1966) introduced this name for the complex of humic horizons occurring above the Eemian hydromorphic soil at Warneton. Later (1966) it was also found as a single horizon on the typical reddish facies of the *Rocourt soil* at another place of the same section. Its striking resemblance with the humic horizon of Tongrinne, permitted pedo-geological correlation between the transitional area and the loess area.

As has been stated by R. PAEPE (1966), this soil is due to an independent soil process and is not, as was set forth by G. MANIL (1947, 1952, 1957), the A horizon of the underlying textural-B-horizon of the *Rocourt soil*. For then one would expect a prominent A_2-horizon from which up to now no traces have ever been found in a outcrop.

It has also already been stated that the *Rocourt soil* is truncated by the overlying solifluction deposits (Warneton, Tongrinne, Poperinge, Zelzate) within which the *Warneton soil* is developed, and that the upperpart of the *Rocourt soil* shows creep structures leaning downslope.

(*) Kindly reported at the occasion of a field-excursion.

Moreover, it is not unusual to find the *Warneton soil* laterally shifted against the *Rocourt soil* instead of overlying the latter one (Poperinge, Warneton). Also, pebbles may be found along the boundary between the two horizons.

Finally the building of the *Warneton soil* started after solifluction came to a standstill. For that matter, the autochtonous character of the *Warneton soil* is supported by the presence of undisturbed crotovines, pearcing even into the *Rocourt soil* and thus giving another argument in favour of the separation of the two soils. So the junction line between the two palaeosoils always coincides with the line of geological discordance between the solifluction and the underlying deposits.

F. GULLENTOPS (1954) earlier considered the humic horizon above the *Rocourt soil* (Rocourt) as an independent soil process. This author however, attributed a Late Eemian age to it. It must be admitted that in the last mentioned locality the *Warneton soil* shows a weaker development and a high degree of transport.

As far as the nature of the soil is concerned, we deal here with a typical AC profile of a steppe soil (chernosem). The presence of a C horizon immediately underneath the A horizon, assumes that no intense pedological weathering has taken place, which as stated by J. FINK (1964) is due to the lack of warmth in winter and humidity in summer. In the C horizon Fe/Mn concretions occur in great abundance, even if lacking in the *Rocourt soil* (Tongrinne). This phenomenon, also reported by J. FINK (1965) in Austria, was there considered as an important bench mark for the base of the Weichsel.

Pedo-geological correlation of the *Rocourt-Warneton soil complex* of Tongrinne with the locus typicus Stillfried in Austria was based on its morpho-stratigraphical resemblance (R. PAEPE, 1966). The *Warneton soil* coincides fully with the upper part of the humic horizon of the Stillfried complex. To the latter an Amersfoort (or even Brørup) interstadial age has been attributed by B. FRENZEL (1965). Pollen investigation of the *Warneton soil* at Poperinge and Antwerp yielded similar results (R. VANHOORNE, p. 59) thus affirming their stratigraphical identity.

1.4.2.4. *Poperinge, Hoboken and Kesselt-Zelzate Soils.*

As this group of soils happens to be displayed within the bulk of the *peaty loam formations* they all must be related to each other in some way.

Like the *Warneton soil,* they are usually of the AC type of profile development although brown colouring of the humic horizon and alternation with brown soils is common (R. PAEPE, 1963, 1965). Generally, however, they are less prominent and affected by cryoturbation activity.

The lowermost member of this group, the *Poperinge soil* occurs outside the loess area only. In the transitional area it appears as a brown humic horizon (Warneton, Poperinge and Rumbeke) or as a peat deposit (Poperinge) which was dated 45.600 y.B.P. In earlier sections, brown soils have been reported from this level and assigned to as Würm I/II interstadial in age (R. PAEPE, 1963, 1965). In the coversand area, the *Poperinge soil* exists faintly although its presence may be conjectured by the occurrence of peaty layers in the fine layered structure of the *peaty loam formations* (Ghent), or of a humic horizon in the top part of the *loams and coarse sands* (Zelzate).

The next following two soils will be commented together because of their close relationship. We will start with the most important one of both.

The *Kesselt soil* was introduced by F. GULLENTOPS (1954) to indicate a weathering zone at the contact between the Hesbayan and Brabantian loess deposits.

Because of its widespread constant morphological aspect, we prefer to refer to it as a *cryoturbated soil horizon.* For the same reason, this soil horizon ranks as a stable stratigraphic horizon in the Late Pleistocene sequence.

In the loess area, the cryoturbated soil is of the brown soil type and may occasionally be mottled with gley. (Tongrinne, Kesselt). In the transitional area brown soils (Ploegsteert, Zonnebeke) as well as brown humic horizons (Poperinge) or still, a drab mottled horizon (Rumbeke) are found and lateral transition between the two soil facies is common (R. PAEPE, 1963, 1965). In the coversand area this horizon occurs as a peat formation (Hoboken, Zelzate) of varying thickness or as a gley mottled, thin, diffuse horizon (cfr. « Gleyfleckenzone », J. FINK, 1964) (Antwerp, Hoboken). The latter facies is seemingly confined to deposits subdued to a high watertable (Scheldt valley).

The *Hoboken soil,* if present, shows close resemblances with the *Kesselt soil* which it is also closely underlying and even adapting its structure to some extent. This is true for the thin, gley mottled horizon at Rumbeke, the strongly cryoturbated horizon at Zelzate and the discontinuous peaty layer at Hoboken. It looks as if it were a thin horizon of the Kesselt soil although less prominent. It may suddenly disappear even when the overlying *Kesselt soil* continues to exist (Zelzate, Rumbeke).

Where the *cryoturbated soil horizon* occurs solely the question rises to which of the two levels it should be accounted for. Thanks to the rather constant appearance of the *Kesselt soil* in its uppermost position at the top of the *peaty loam formations* or their counterpart, its assimilation with a single *cryoturbated soil horizon* is evident. This confirms again the correlation of the *Zelzate soil* (28,200 y.B.P.) with the *Kesselt soil;* it is a matter of course then to assimilate the underlying cryoturbated horizon amidst the *peaty loam formations* with the *Hoboken soil* (32,490 y.B.P.).

In connection with this, it can be stated, that similar to the Dutch palaeosoil stratigraphy, in Belgium two soils horizons seem to occur within the reach of the Paudorf interstadial dated 28.120 y.B.P. and 27.990 y.B.P. (J. FINK, 1961) at Stillfried (Stillfried B). In the Netherlands the Denekamp interstadial, which is also the uppermost palaeosoil of the « loam beds and peat » (*) was fixed at between 32.000 and 29.000 y.B.P. while the Hengelo interstadial lasted from approximately 39.000 to 37.000 y.B.P. (T. VAN DER HAMMEN et al., 1967). It may thus be that the radiocarbon date of the *Hoboken soil* is too young.

(*) Independently from our denomination «*peaty loam formations*» the connotation «loam beds and peat» was introduced by the Dutch investigators, at almost the same time, for the same kind of deposits in the Netherlands.

From the foregoing, it can be concluded that throughout the period of building up of the *peaty loam formations* similar palaeoclimatic conditions with regard to soil development, prevailed periodically. The appearance of brown soils and brown humic horizons pleads in favour of a higher degree of humidity, causing more intensive mineral weathering than at the time of the steppe soil (*Warneton soil*) building. Also temperature was generally higher than in the previous period (cryoturbation).

The geographical distribution of the soil types, and according to this, the distinction of three facies provinces, permit the following statements: the loam area was subject to more dry conditions than the transitional area and probably the coversand area was the wettest of all. Contrary to the time of the *Warneton soil* formation, regional differentiation of the palaeo-climate was more prominent during formation of the *Kesselt-Zelzate soil*. One is justified to attribute this to the mild character of the climate.

Finally, stress must be laid upon the most particular position of the *Kesselt-Zelzate soil.* It appears at the end of a continuous sedimentation within which a recurrence system of soils happened to develop. We believe that the *Kesselt-Zelzate soil* does not represent a sudden break in the palaeoclimatic conditions. One must rather look at it as if ultimately, the palaeoclimate became stable over a long period of time whereas before, fluctuations favouring plant growth and soil development were relatively short. With respect to this, one can easily understand the absence in some areas of the lower members of this vertical sequence of soils eventhough the *Kesselt-Zelzate soil* has developed.

1.4.2.5. *Stabroek Soil.*

P. Greguss, F. De Coninck and R. Vanhoorne (1966) were the first to identify peaty horizons overlying coversand deposits at Stabroek as belonging to the Bølling oscillations. Their radiocarbon dates (GrN-3049: 12.330 ± 120 y.B.P. GrN-3052, 12.340 ± 120 y. B.P. and GrN-2458, 12.460 ± 140 y.B.P.) tally perfectly with the one obtained at Zelzate for the peaty bands overlying *coversand 2:* 12.300 y.B.P. Therefore, we propose to call this level the *Stabroek soil.*

1.5. CHRONOLOGY OF THE LITHO-STRATIGRAPHICAL UNITS — SUMMARY.

This summarising paragraph aims the chronological arrangement of the litho-stratigraphical units (table 1). Time being an abstract notion, the time-stratigraphical classification will be based on the effects due to periodical changes of the environment. This necessitates a review of the various climatological-geomorphological conditions which controlled the environmental processes and which, conversely, must be interpreted after the sedimentation pattern of the various litho-stratigraphical units.

R. Tavernier, 1954, attributed to the Late Pleistocene in Belgium both Eemian and Würmian periods. With the present knowledge, we think Belgium fits more in the Northern European classification system and therefore the term Weichsel is more likely to be used than Würm with respect to the Last Glaciation.

1.5.1. The Eemian Period.

From the studies made in the various sedimentation areas, it follows that the Eemian deposits may show quite a different outlook from one place to another.

In the loess area, the Eem is represented solely by the *Rocourt soil* which shows a common repartition on top of the Saale loess. If the latter is lacking, no traces of Eemian deposits are found. It is in this area too that morpho-stratigraphical resemblance was established with the Göttweig soil of the Stillfried complex in Austria (see R. Paepe, 1966).

In the transitional area, this last interglacial may sporadically be represented under the facies of the *Rocourt soil* beneath a relatively thin loess cover or as *peat and gravels*, eventually *peat and loams* (Rumbeke), at the bottom of deep, buried thalwegs.

In the coversand area, soil relicts as we saw are of minor importance for that period. *Peat and gravels*, lying directly on the tertiary substratum, are by and large the most common feature and excel both in lateral and vertical extension

TIME STRATIGRAPHICAL UNITS		LITHOLOGICAL UNITS AND SOILS			PERI-GLACIAL FEATURES	14C-DATINGS
		LOESS AREA	TRANSITIONAL AREA	COVERSAND AREA		
(Holocene)						
LATE GLACIAL		?	LATE COVERSAND 2	LATE COVERSAND 2		
	ALLERØD		FINE FROST WEDGES	HUMIC LAYER, FINE FROST WEDGES, CRYOTURBATIONS		
		?	LATE COVERSAND 1	LATE COVERSAND 1		
	BØLLING		DESERT PAVEMENT AND FINE FROST WEDGES	PEAT AND LOAM (STABROEK SOIL)		12.300
PLENI-GLACIAL B		COVERLOAM 2	COVERSAND 2	COVERSAND 2		
		Desert pavement 3 and large frost wedge row				
		COVERLOAM 1	COVERSAND 1 / COVERLOAM 1 / CROSS BEDDED SANDS	CROSS BEDDED SANDS / COVERSAND 1		
PLENI-GLACIAL A		Desert pavement 2 and fine frost wedge row				
	PAUDORF INTERSTADIAL	CRYOTURBATED SOIL HORIZON: KESSELT SOIL (BROWN SOIL)	(BROWN HUMIC SOIL AND PEAT)	ZELZATE SOIL (GLEY MOTTLED ZONE AND PEAT)		28.200
		LOESS	PEATY	COVERSAND		
			GLEY MOTTLED ZONE	HOBOKEN S. PEATY		32.490
		LOAM FORMATIONS	LOAM FORMATIONS	SAND FORMATIONS		
		LOESS	FORMATIONS	COVERSAND		
			PEATY / POPERINGE SOIL	PEATY		45.600
		Desert pavement 1 and small frost wedge row				
	BRØRUP & AMERSFOORT INTERSTADIALS	STEPPE SOIL / LOAMS	WARNETON: STEPPE SOIL / STEPPE SOIL / STEPPE SOIL; LOAMS AND COARSE SANDS	PEAT / LOAMS AND COARSE SANDS / PEATY		
		SANDS AND GRAVELS		SAND AND GRAVELS ANTWERP SOIL = PODZOL		
EEM INTER-GLACIAL		ROCOURT SOIL	ROCOURT SOIL; RUMBEKE 2 PEAT / FLUVIATILE CLAY, LOAMS, SANDS / RUMBEKE 1 PEAT	ROCOURT SOIL; PEAT AND GRAVELS		

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Table 1 — Symbols used to indicate periglacial features are inspired after a recent Dutch paper by T. van der Hammen et al. Zones represented by hachures indicate a hiatus.

their counterparts of other area's. The moreover, they are easily to recognize not only by the presence of guide fossils such as *Corbicula fluminalis* and especially *Tapes senescens*, but also because of their fluviatile character and the form of the thalweg which they fill up. The latter valley forms are always much deeper and more V-shaped contrary to the ones observed in the Weichselian deposits. This facies of the Eemian deposits is the most southern extension of the « Senescens Sande » (R. PAEPE, 1966) thanks to which we are able to assure the stratigraphical position of the *Rocourt soil* and by extension, to integrate the Belgian Late Pleistocene within the Northern European classification system.

Notwithstanding the fact that the climate as a whole was generally warmer and more humid, (soil, guide fossils and also vegetation) during this period, the environmental conditions, inducing the geomorphological processes differed greatly from one area to another.

Concentrated, fluviatile erosion and subsequent fluviatile sedimentation, widely spread in the coversand area (Flemish Valley, Scheldt valley), was however restricted to local gullies in the transitional area and was still less important in the loess area. In the latter area, soil development therefore was strongest and shows also a great constancy as to extension.

Presumably a number of valleys within which the Eem deposits were laid down never existed before the Eemian period. For otherwise the stepwise incision, with concordant colmatation as was observed at Antwerp (West Bank) and earlier also at Poperinge (R. PAEPE, 1963, 1965), cannot be explained. Seemingly two cycles of erosion and subsequent sedimentation succeeded for the valley form (Antwerp) as well as the nature of the sediment (Ghent) conjecture these two phases of formation. On the other hand, in the transitional area the underlying Saale deposits are found always to be fluviatile in nature too so that the fluviatile system dating from the Eem period was probably influenced by the already preexisting relief.

1.5.2. THE WEICHSELIAN PERIOD.

1.5.2.1. *Period of the «SANDS AND GRAVELS» Deposition.*

From the coversand area, more especially from both the Scheldt valley (Antwerp, Hoboken) and the Flemish Valley (Zelzate), it has become clear now that the lowermost Weichselian bed is a fluviatile deposit build up by what we called *sands and gravels*. Actually they erode partly the *peat and gravels* of Eemian age from which they are separated by a line of discordance with sporadically frost wedges (Antwerp).

Another point, which adds to the assumption of a new period for these deposits, is the flat and shallow valley form outlined by these series, contrasting sharply with the thalwegs of the Eem period. Moreover as we already saw, the *sands and gravels* may extend laterally (outside the valley) as a thin gravel layer immediately overlying the tertiary substratum (Antwerp) which is an indication that lateral supply of sediment load had become important at that time.

This is a geomorphological-sedimentological feature never observed in the sedimentation pattern of the Eem deposits. It is a most important one for if it were not of this, the *sands and gravels* would often be difficult to distinguish from the *peat and gravels* in the field.

It seems thus that the erosion/sedimentation processes became entirely different at that time and were controlled by the mode of evacuation of the superficial water from the environment. Instead of water concentration into gullies, a widespread surface phenomenon inducing important sheet-like erosion was active which we are inclined to connect with episodic solifluction processes. Lateral supply caused a rapid increase of river load and a weakened capacity to erode, resulting in the shaping of a flat valley bottom.

It is also noteworthy that the thin gravel layer contains palaeolithic implements characterized by a high degree of technique of development (Levalloisian point) so that again a Weichselian age must be assumed.

The very beginning of this sedimentation coincides with the development of the *Antwerp soil*, for the A_2-horizon affects the lower part of the gravels only. The increase of humic elements in the upper part of the A_2-horizon may be the remnants of the original A_1-horizon, stripped off by subsequent erosion. Consequently we assume that during the sedimentation of the *sands and gravels* long periods of emersion occurred admitting soil formation followed by new erosion.

From the afore, one is justified to assume that environmental conditions became periglacial at that time and the climatic oscillation involved with this change, although still considerably wet and relatively warm (soil formation) may be looked at as a first symptom of decay after the Eem period. But as we shall see later, the lithological affinity of these deposits with the *peat and gravels* is still greater than with the overlying Weichselian deposits, implying that the after-effect of the Eem climate must still have been felt strongly.

It must be stressed that outside the mentioned valley areas the presence of the *sands and gravels* has been observed only sporadically up to now (Racour). They may even be lacking in parts of the coversand area denominated as the sand belt (Sint-Niklaas) and they fail to exist almost entirely in the transitional area.

1.5.2.2. *Period of the «LOAMS AND COARSE SANDS» Deposition.*

The *sands and gravels* in the afore mentioned localities are overlain by *loams and coarse sands* which form in all other observed places the base of the Weichselian deposits. So we assume that generally a litho-stratigraphical hiatus exists between the Eem and Weichsel periods in the Belgian Late Pleistocene sequence.

Two diagnostic facies of this sedimentation were yielded from the transitional area. The most commonly propagated one, after which these series were called, is the facies found to fill up small ravination gullies, consisting of alternating coarse sand and sandy loam layers, occasionally intermingled with peaty horizons (recurrences of the *Warneton soil*). Another striking aspect of these series is their mixted fluviatile and above all solifluction structure within which bound cryoturbations and frost wedges are still preserved. A similar facies is found back in the coversand area (Zelzate, Sint-Niklaas) but here fluviatile activity was apparently stronger if not the most important one (Antwerp). Indeed at the latter locality, the *loams and coarse sands* may occupy the particular position of a back swamp going laterally over into a pure river deposit (Antwerp, left bank). Whatever the local differences may be, the common characteristic of these fluviatile deposits conjectures sedimentation by a heavy loaded (braided) watercourse with low velocity supplied by lateral solifluction flows. Finally they also may be lacking completely when eroded by the overlying deposits.

The other facies lies on the uprising Saale loess or *Rocourt soil* above or underneath one unique layer of the *Warneton soil.*

The texture of the deposit is then outspoken loamy and solifluction is by and large the dominating pattern. Lateral transition with the above mentioned facies is a common feature in the transitional area (Warneton, Poperinge, Rumbeke).

This facies is, as far as we know, the solely propagated one in the loess area but there usually overlain by the *Warneton soil* (Tongrinne).

From what preceeded it may be stressed that as a whole episodic solifluction controlled widely the sedimentation processes of the period and even more strongly than during the deposition of the *sands and gravels* but here too regional differentiation can still be observed.

Also erosion was a product of solifluction for it could be stated in both the transitional (Warneton, Rumbeke) and loess areas (Tongrinne) that the solifluction structures in the top layers of the Saale loam and/or *Rocourt soil* stand in close relationship with structures of the overlying solifluction deposits. Therefore gullying and ravination along the line of contact between the Eem and Weichsel deposits are simultaneous with the solifluction processes that affected the *loams and coarse sands.*

It may then be concluded that both sedimentation and erosion are a result of (episodic) solifluction processes which in turn are known to be due to periglacial climatic conditions. Therefore, independently from the fact whether they are underlain by the *sands and gravels* or not, the appearance of the *loams and coarse sands* in the field proves that one deals already with Weichsel Glacial deposits. As of then, it may also be stated that solifluction in the basal deposits of the Weichsel should no longer be considered as a casually occurring phenomenon but as a widespread geomorphological process dominating and characterizing the beginning of the Weichsel sequence.

Whereas the *sands and gravels* witnessed of a transitional climatic oscillation, showing still some affinity with the conditions prevailing during the Eem, we are inclined to classify the *loams and coarse sands* fully within the pleniglacial phase of the Weichsel. Otherwise the high frequency of different kinds of periglacial phenomena at several levels in these deposits cannot be explained and yet they give proof of a more severe climate than the former one.

But even if the climate as a whole were more rigid, it is still fluctuating as follows from the alternation of the periglacial features. Then periods of thaw were sufficiently important to explain episodic solifluction on the dry plateau's (loess area and parts of the transitional area) and a combined solifluidal-fluviatile activity in the more humid regions (coversand area and gullies of the transitional area).

This unstable character of the climate is furthermore deduced from the fact that soil development could take place at several moments of this sedimentation phase. Indeed the (steppic) *Warneton soil* complex is an indication of periodically prevailing dry climatic conditions, which lead to the assumption of the existence (besides the distinction of minor fluctuations within the humid solifluction periods), of major oscillations between dry and wet. We leave beyond question whether these fluctuations must be interpreted as an alternation of stadial and interstadial phases.

It is the first time that we observe in the stratigraphical sequence the coming of extreme dry periods which ultimately result in the development of *desert pavement 1 with small frost wedge row.*

But as stated earlier, the local appearance of this stone line as well as the limited size of the *small frost wedge row* lead further to the assumption that one deals here only with a relatively minor cold-dry fluctuation of short duration.

1.5.2.3. *Period of the «PEATY LOAM FORMATIONS» Deposition.*

Actually, after the formation of *desert pavement 1* the climate turned over to humid conditions, again, resulting in the sedimentation of the *peaty loam formations.* If peaty horizons are lacking, they are referred to as *loam formations* and still, if the texture reveals to be sandy, they are called *sand formations.*

These series usually overly the *loams and coarse sands* but may also be found either directly on the *peat and gravels* (Ghent) or on underlying pre-Weichsel or even Tertiary deposits (Poperinge, Rumbeke, Volkegem).

As stated earlier, the diagnostic feature of these series is the quick alternation of regularly disposed loam and sandy loam layers, recalling the morphology of a varve system affected by periodic solifluction. However, they cannot have been originally an underwater deposit, for they do occur also, as mentioned previously, under the same aspect in a plateau position (Tongrinne) and furthermore they show too many microcryoturbation disturbances as well as solifluction structures.

Yet, we think that prior to the solifluction activity, these deposits were niveo-fluvial in origin; their texture let no doubt about an initial eolian transport, whereafter they were taken up again by superficial melt water and redeposited periodically as fine sheets. After sedimentation of each sheet renewed freezing may have opened little frost wedges, an activity which, as we stated earlier, was also limited in time and intensity to the cycle of one sheet. Ultimately, subsequent thaw and freeze disturbed the newly deposited layer and gave to it its definite solifluction morphology. Hereupon a new sheet was laid down which underwent the same cycle as the previous one.

Such periodic solifluction was the only process in the loess area (Tongrinne) but in both the transitional and coversand areas, fluviatile activity played an important role too and is accompanied by development of peaty layers (*peaty loam formations*).

In this connection, the profiles provided by the Sifferdock section at Ghent, and by the excavations at Wevelgem and Harelbeke must be reminded. There, as has been mentioned above, the succession of solifluction, strong peaty loam layers overlain by fluviatile less peaty loam layers in turn covered by a thin veneer of eolised sands overlying a fine frost wedge row, is repeated at least four times. This sequence remembers to the fact that in other places thick pure eolian loess (Tongrinne) or eolian sand (Hoboken) beds were found interfering with the solifluction deposits, building up jointly the (*peaty*) *loam formations*, while still in other places thin pebble bands were found separating the solifluction deposits (Rumbeke, Wevelgem).

It is a matter of course then to conclude that besides the periodical sedimentation of the solifluction deposits another sequence of major climatic changes (at least four) is found within the deposition of the *peaty loam formations:* periodic solifluction followed by fluvial and ultimately by an eolian sedimentation after a period of frost activity and local desert pavement development.

As of then each sedimentation cycle looks as if it were a microform of the previous *loams and coarse sands* sedimentation. The *peaty loam formations* are then considered as a recurrence system of the *loams and coarse sands*, characterized by an acceleration of the sedimentation processes.

From a climatic point of view, this sedimentation excels by its frequent changes from cold-wet to cold-dry conditions, a variation which is felt in the coversand and to some extent also in the transitional area more strongly than in the loess area. The instability of the climate points, in our opinion, to the mild character of the climate as a whole, an assumption which is supported by the presence not only of peat but also of important soil horizons.

Indeed maybe four, certainly three periods are distinguished (Poperinge: 45.600 y.B.P.; Hoboken: 32.490 y.B.P.; Zelzate-Kesselt: 28.200 y.B.P.) and they do tally pretty well with radiocarbon dates of other countries, especially the Netherlands and Austria.

The most constant and latest of these soils, the *Kesselt-Zelzate soil* (*cryoturbated soil horizon*) with its faremost prominent development is then another climatical bench mark. For it looks as if the mild conditions finally attained a point of such stability and dominance that soil formation lead to the development of different soil types (brown soil, gley horizon, peat) with regional repartition. But nevertheless, as this horizon is affected by large cryoturbations and covered with a *fine frost wedge row* and *desert pavement 2*, it may be looked at as the final phase of the four mentioned cycles only differing from the others quantitively.

If one agrees now to attribute to this long stable, mild climatic phase an interstadial character then one may see that it was prepared during a long period of climatic struggle. Both from its stratigraphical position and its absolute age, it is obvious that this level corresponds with the Paudorf interstadial.

Overlooking the climatic changes eversince the onset of the *loams and coarse sands* deposition it seems that the period of decay of the climate, reaching its maximum at the time of the *small frost wedge/desert pavement 1* formation, was less exposed to quick alternations than the period following hereafter and leading to the Paudorf interstadial. Besides this frequency differentiation no other characteristics separate both lithostratigraphic phases so that they jointly represent the first cold period of the Weichsel with a small cold-dry climatic high. We shall therefore indicate this period up to the *desert pavement 2 — fine frost wedge* level with the connotation Pleniglacial A.

Geomorphologically speaking, the period of the *peaty loam formations* contributed in a greater extent to the flattening of the relief than the period of the *loams and coarse sands*. For the dominance of the subhorizontal deposition of the solifluction layers and levelling by the pebble band formation, resulted in a smooth relief at the threshold of the Kesselt-Zelzate interstadial, locally reinforced by the development of *desert pavement 2*. Sedimentation was by far more important than erosion so that colmatation of the depressions reached a point where differences in height between the « tertiary » humps and the colmatated depressions were reduced to a few metres only.

1.5.2.4. *Periods of the « COVERLOAMS, COVERSANDS and CROSS BEDDED SANDS » Deposition.*

In sharp contrast with the previous series stand the lithological units mentioned under this heading. They are a result of differences in both texture and mode of sedimentation, while also regional differentiation is observed. The whole is classified as Pleniglacial B.

The transitional area solely comprises the various lithologic units of the period and lateral interfingering of these units was found especially at Poperinge.

There, the lithological units revealed to be closely related with their topographical-morphological position. Indeed, in the undeep lower (valley) parts, fluviatile *cross bedded sands* dominate, going abruptly over, while rising up along the plateau edge, into pure eolian loess (*coverloam 1*) and then further to the very plateau top into a fine mixed layered deposit of sand and loam (*coversand 1*). In the major river systems (Scheldt valley: Erquelinnes, Hérinnes; Lys valley North of the Flemish Hills: Wevelgem, Harelbeke), sedimentation behaved entirely as in the Flemish valley North of Ghent.

The whole is overlain by another more continuous series of mixed layered sands and loams (*coversand 2*) separated from the underlying series by the *large frost wedge row* and by *desert pavement 3*. The latter may laterally also develop as a cross bedded sand deposit when overlying the already mentioned lowerpart of the *cross bedded sands*.

From the above, we conclude to the important statement that the *cross bedded sands* are contemporaneous of the coverloam and coversand deposits; with other words, purely fluviatile conditions and eolian sedimentation exist simultaneously and stand in close relationship with each other at that time.

In the coversand area *cross bedded sands* are commonly found as a thick (3-4 m) continuous deposit in the large thalwegs (Flemish Valley) overlain by *coversand 1*. The latter is composed of two beds of fine eolian sands (Zelzate) but often fluvial structures are striking. Two phases can be distinguished separated by a cryoturbation zone developed in a more loamy textured material (Zelzate). Hereupon *coversand 2* extends as a thin, homogeneous eolian sand deposit, overlying the large *frost wedge row* and *desert pavement 3*. Earlier, the latter sands were referred to as Earliest Dryas, but we shall come back to this point later.

Elsewhere in the coversand area, only a thin pure eolian sand cover is present (Sint-Niklaas, Antwerp, Hoboken) overlying a *large frost wedge row* so that they are classified as *coversand 2*.

In the loess area, the farmost dominating deposit is a thick eolian coverloam. The main part of it probably tallies with a lower part of *coverloam 1* for at their top, they carry cryoturbatic undulations (Volkegem, Geraardsbergen) which were earlier correlated with the cryoturbation zone of *coversand 1* at Zelzate. In other places (Tongrinne), only *coverloam 2* is present, overlying the *large frost wedge row*, but then less thick and with fluvial, structures in the lower part.

It can now be stated that coverloam or coversand deposits if thin, are very probably to be considered as belonging to that part of the Pleniglacial B following on the *large frost wedge row — desert pavement 3*. This may be helpful when interpreting borings.

A special facies of *coverloam 1* is found at Warneton and dated thanks to the presence of the cryoturbatic undulations immediately overlain by the *large frost wedge row* at its top. It is a mixed layering of reworked heavy Tertiary clay and loam, sheetwise deposited by water.

The former review leads to the conclusion that sedimentation shows its greatest, regional variation during the Pleniglacial B. Nevertheless, it was possible to derive some general conclusions: sedimentation was strongest and characterized by a great variety of both texture and mode of sedimentation during the first phase of the cover deposits; it was purely eolian in the loess area and strongly influenced by fluvial and fluviatile activity in the coversand area. In between, the transitional area reveals to be an environment where both processes and texture stand in a delicate adjustment to each other.

During the second phase, fine coversand deposition dominates in both transitional and coversand areas whereas loess was the only deposit in the loam area.

Another point is that it leaves no doubt that in relatively humid areas, fluvial activity contributes, to a greater extent, to the thickness of the deposits than eolian activity, except for wind protected troughs as the Flemish Valley. In dry areas, as the loam belt, eolian activity is the most important aggradation factor.

Nevertheless, the overwhole importance of eolian activity at that time plead in favour of extreme cold-dry climatic conditions. Therefore stream development was unsignificant and the *cross bedded sands* are to be considered as snow melt water deposits. This is also supported by the fact that in the loess area, where, according to the nature of the sediment (loess), extreme cold-dry conditions prevailed, no *cross bedded sands* were found. Also under such conditions the sea level must have been low so that one would expect deep erosion rather than undeep accumulation at this level.

The establishment of *desert pavement 3* preludes the arrival of the maximum cold which finds its utmost expression in the *large frost wedges*. Their development lasted for a long period of time during which sedimentation was overwhelmed by deflation. Deposition of *coverloam 2* and *coversand 2* must be considered as the onset of milder climatic conditions, but complete lack of fluviatile structures implies still dryer and colder conditions than during sedimentation of the first phase of cover deposits. At Zelzate, this *coversand 2* shows fluviatile and cryoturbatically structured, loamy layers in its upper part preluding a new climatic oscillation.

The deposition of the cover deposits continued the smoothening of the relief and inherited to a large extent the relief dating from the end of the Pleniglacial A.

1.5.2.5. *Period of the «LATE COVERSAND» Deposition.*

From the Flemish Valley good insight was yielded in the sandy deposits overlying the coversands and called late coversand.

At Zelzate, these series start with three or four peaty bands (*Stabroek soil*, 12.300 y.B.P.) forming a continuous boundery between the coversand and the late coversand deposits. It is the first time since the Kesselt-Zelzate interstadial that real peat beds were met again pointing to a considerable improvement of the climate known generally under the name of Bølling oscillation. The *late coversand 1* which follows upon this Bølling horizon still reveals fluviatile structures especially at its base while higher up the sedimentation becomes purely eolian. It is not sure whether or not the humic horizon at the base of the eolian sands must be considered as the Allerød oscillation, but the diffuse frost wedges at this level may be an important bench mark.

In the transitional area the late coversands form a thin cover (max. 1 m) and separation from the Pleniglacial B must often be conjectured from differences in both texture and structure between the *coversand 2* and *late coversand 1*. Here too, the latter facies is again characterized by fluviatile structures and the texture is slightly more loamy than *coversand 2*. In some cases, fine frost wedges are found along the line of contact (Rumbeke, Poperinge) occasionally with a fine desert pavement above it.

Also *late coversand 2* recalls the facies of Zelzate revealing a purely eolian origin and is often separated from *late coversand 1* by another row of fine frost wedges. No traces of Late Glacial deposits were found in the loess area, up to now.

But for the peaty beds, the Late Glacial sedimentation resembles closely to the one dating from the Pleniglacial B, especially to *coversand 2*.

It may thus be presumed that during the eolian sedimentation the climate was still cold and dry and to some extent similar to the one prevailing during the Pleniglacial B, but of shorter duration. From this it follows that climatic fluctuation between mild and cold-dry occurred more frequently and therefore it is reasonable to classify the whole series as Late (Weichsel) Glacial to begin with the Bølling. There is no reason, whatsoever, for accounting *coversand 2* (former Earliest Dryas) to the Late Glacial, the *large frost wedge row—desert pavement 3* boundary being the bench mark of the maximum cold and not of a thorough change towards milder climatic conditions.

As of then, another aspect may be set forth: an increasing number of sedimentation cycles followed the climatic high of the Pleniglacial B. This recalls the acceleration of the sedimentation already observed in the *peaty loam formation* following on the first, cold-dry high of the Pleniglacial A. So it may be concluded as to the similarity in the rythm of sedimentation between the cold-wet Pleniglacial A and the cold-dry Pleniglacial B. Furthermore, whereas the *peaty loam formations* were considered as a recurrence system of the *loams and coarse sands*, *coversand 2* and the *late coversands* combined are now interpreted as a recurrence system of the *coversand 1* deposit both as a result of a climatic evolution towards milder conditions.

But for the Flemish Valley (Zelzate) and the Scheldt plain sites, the entire sequence of Late Glacial deposits forms a thin cover usually not exceeding 1 m thickness and is thus of little if any effect in the geomorphological shaping of the landscape as a whole and seems to be negligible in the loess area. At that time, deflation was probably a still more important process than sedimentation which took place only in preferential areas: i.e. the thalweg of the Flemish Valley, which was not only protected against strong winds but still had a higher watertable than in other areas favourising dune building (R. TAVERNIER, 1954; F. GULLENTOPS, 1954). On the contrary drought in the open loess area may have encouraged eolian activity so much that probably here very little if any sedimentation occurred.

1.5.3. DISCUSSION.

We assembled the classification set forth in the previous chapters and an attempt was made for correlation with the classification of other Belgian authors (table 2). In the following discussion we shall also refer to recent classification systems of other European countries.

The boundary between the Eemian and Weichselian periods had to be lowered because of the intercalation of the *sands and gravels* between the *loams and coarse sands—Warneton soil* and the *peat and gravels*.

Up to now, the *Warneton soil* even whitout being indicated with our connotation, was considered either as the very base of the Würm I (facies humifère; R. TAVERNIER and J. DE HEINZELIN, 1957) or as the colder upper part of the Eemian (F. GULLENTOPS, 1954). It is clear now that the *Warneton soil* complex (R. PAEPE, 1963, 1966) is the counterpart, undoubtedly of the Amersfoort, maybe also of the Brørup interstadial in the Netherlands (W.H. ZAGWIJN, 1961), the upper, humic part of the Stillfried A in Austria (J. FINK, 1962) and the « Bilshäuser Boden Komplex » in Germany (H. ROHDENBURG and B. MEYER, 1966). As this soil complex paves in most places the base of the Last Glacial, a stratigraphical hiatus reveals to be generally present between the Eemian and the Weichselian periods in Belgium. Furthermore this soil of steppic nature is enveloped in the *loams and coarse sands* which from a sedimentation point of view must be considered as Pleniglacial and therefore we are inclined to reject the expression Early Weichselian for these deposits.

Moreover the *sands and gravels* occupy a lithostratigraphic position in the Pleniglacial A similar to the *cross bedded sands* of the Pleniglacial B and their adherence to the Pleniglacial A does, in

R. TAVERNIER, J. DE HEINZELIN 1957	
ÉPI - PLÉISTOCÈNE	DRYAS SUPÉRIEUR
	ALLERØD
	DRYAS MOYEN ET INFÉRIEUR
	LEHM
	ALLUVIONS & COLLUVIONS
PLÉISTOCENE SUPÉRIEUR	LOESS RÉCENT III (WÜRM III)
	LEHM = SOL DE KESSELT
	LOESS RÉCENT II (WÜRM II)
	LEHM = SOL DE CLYPOT
	LOESS RÉCENT I (WÜRM I)
	FACIÈS HUMIFÈRE
?	LIMON FENOILLÉ (EÉMIEN)
	LIMON ANCIEN (RISS)

F. GULLENTOPS 1954		
PLÉISTOCÈNE SUPÉRIEUR	TARDIGLACIAIRE	DRYAS RÉCENT
		ALLERØD
		DRYAS ANCIEN
		BØLLING
		?
	PLÉNIGLACIAIRE WÜRM	BRABANTIEN
		SOL DE KESSELT
		HESBAYEN
	EÉMIEN	LIMON HUMIFÈRE
		SOL DE ROCOURT
	RISS	HENNUYEN

R. PAEPE 1966				
UPPER PLEISTOCENE	WEICHSEL LATE GLACIAL	LATE DRYAS		
		ALLERØD		12330 Y.B.P.
		EARLY DRYAS		12340 Y.B.P. 12460 Y.B.P.
		BØLLING	STABROEK SOIL	12.300 Y.B.P.
	WEICHSEL PLENIGL. B	COVERLOAM 2 OR COVERSAND 2		
		COVERLOAM 1 OR COVERSAND 1 / CROSS BEDDED SANDS		
	WEICHSEL PLENIGLACIAL A	CRYOTURBATED SOIL HORIZON	ZELZATE SOIL	28.200 Y.B.P.
		PEATY LOAM FORMATION	HOBOKEN SOIL	32.490 Y.B.P.
			POPERINGE SOIL	45.600 Y.B.P.
		LOAMS AND COARSE SANDS	WARNETON SOIL	
		SANDS AND GRAVELS	ANTWERP SOIL (?)	
	EEM.	PEAT AND GRAVELS	ROCOURT SOIL.	
MIDDLE PLEIS.	SAALE	LOESS		

Table 2

some way, complete the sedimentation cycle of this first cold-wet phase of the Weichselian.

The *loams and coarse sands* then presumably tally with the whole of the Würm I deposits of R. TAVERNIER and J. DE HEINZELIN, and partly with the lower part of F. GULLENTOPS' Hesbayan. In the Netherlands, these deposits are referred to, recently, as loamy coversand, niveo-fluviatile and coarse coversand, the lower part of which holds the Amersfoort and Brørup interstadials and therefore mentioned separatedly as Early Weichselian (W.H. ZAGWIJN, 1961; Th. VAN DER HAMMEN et al., 1967).

The *peaty loam formations* which build up the upper part of the Pleniglacial A, tally entirely with the Würm II of R. TAVERNIER and J. DE HEINZELIN and constitute the upper part of F. GULLENTOPS' Hesbayan.

R. TAVERNIER and J. DE HEINZELIN separated the Würm I and Würm II by one single soil horizon called « sol de Clypot », although they never elucidated the position of this horizon in a specific paper. Very probably one deals here with one of the soil horizons occurring in the bulk of the *peaty loam formations*. It might be that it concerns the *Poperinge soil* if it is sure that the Clypot soil occupies a basal position. Instead of using a soil horizon, since there are so many, it seems more fruitfull to look for the *small frost wedge—desert pavement 1* boundary at this level.

But, as we have seen, there is no reason, sedimentologically speaking, for introducing a new glacial (Würm II) phase, whatsoever.

The diagnostic importance of the *peaty loam formations* is supported by their widespread occurrence in Europe; they are called « Loamy beds and peat » in the Netherlands (T. van der HAMMEN et al., 1967) and « solifluction » deposits (J. FINK, 1965; H. ROHDENBURG, 1966) in Germany and Austria. The latter facies shows then a striking resemblance with our *loam formations* of the loess area.

Also the same soil horizons were assumingly recognized: the *Poperinge soil* (45.600 y.B.P.) may then be correlated with the « Niedervellmarer Boden Komplex » of Germany and with some of the peaty horizons found at Moershoofd (the Netherlands) by W.H. ZAGWIJN (1961) and dated 46.400 y.B.P.

The *Hoboken soil* is correlated with the Hengelo horizon (the Netherlands) and the « Kirchberger Boden » (Germany).

Finally our *Kesselt-Zelzate horizon* infers perfectly with the internationally known Paudorf soil, and more especially with the Denekamp horizon (the Netherlands) and the « Lohner Boden Komplex » (Germany). It is the major break of the Würm Glacial as stated earlier by J. FINK for the Lower-Austrian loess sequences, since it occurs at the stratigraphical boundary between the Pleniglacial A and B phases.

The first phase of the Pleniglacial B comprises the Würm III of R. TAVERNIER and J. DE HEINZELIN and the Brabantian of F. GULLENTOPS.

In both the latter classifications the upwards extension of the Pleniglacial B is limited by what we have called the *large frost wedge row — desert pavement 3*. We have seen that it is reasonable to classify also the eolian sandy cover up to the Bølling oscillation within the Pleniglacial to which in accordance with the Dutch terminology, the connotation, *coversand 2* or *coverloam 2* was given.

The latter then presumably is to be correlated with R. TAVERNIER and J. DE HEINZELIN's « Alluvions et colluvions » since these authors put the combined « Dryas inférieur et moyen » above a lehm horizon. This lehm, however, might be the pedological counterpart of the Bølling, but then this does not suit in their classification system.

The later phases of the Late Glacial are usually recognized and called successively *late coversand 1* and *late coversand 2*. In our opinion, the first one tallies with the higher mentioned « Dryas inférieur et moyen » whilst the second one is the equivalent of the « Dryas supérieur » of R. TAVERNIER and J. DE HEINZELIN.

1.5.4. BI-CYCLIC SEDIMENTATION SYSTEM OF THE WEICHSEL

We can now trace the climatical-sedimentological evolution of the Weichsel in the periglacial area. The Pleniglacial A is subdivided into four major phases which we have called: the *sands and gravels*, the *loams and coarse sands*, the *desert pavement 1/small frost wedge row* and the *peaty loam formations*. These phases have the common characteristic of being controlled by overwhole cold-wet environmental conditions. This climatic period can however be subdivided into two parts by a cold-dry oscillation (*small frost wedge row*). During the first part of the Pleniglacial A the sedimentation evolved gradually from fluviatile (*sands and gravels*) towards episodic solifluction (*loams and coarse sands*) then eolian before severe cold (*desert pavement 1/small frost wedge row*); the second phase, characterized by finer textured sediments, is then a recurrence system of the first sedimentation cycle revealing also an acceleration in the sedimentation rythm and dominated by periodic solifluction (*peaty loam formations*).

The Pleniglacial B and Late Glacial jointly produce six major phases called by us: the *cross bedded sands*, the *coverloam 1* or *coversand 1* the *desert pavement 3/large frost wedge row*, the *coverloam 2* or *coversand 2*, the *late coversand 1* and the *late coversand 2*. These phases were generally controlled by cold-dry conditions with a severe maximum situated at the *large frost wedge* level. As for the Pleniglacial A, at the beginning of the first part of the Pleniglacial B, the sedimentation was fluviatile (*cross bedded sands*) whereafter a gradual change to eolian activity (*coversand 1* and *coverloam 1*) followed and a maximum cold at the time of the *large frost wedge* formation. Hereafter fine eolian sedimentation dominated (*coversand 2; coverloam 2* and the *late coversands*) during which the phases followed each other at an increased rythm. This recalls the accelerated sedimentation process characterizing the formation of the *peaty loam formation* of the Pleniglacial A, after the first severe cold.

From the afore we conclude that during the Weichsel Glaciation the periglacial sedimentation is characterized by two complete and independant cycles: on the one side the Pleniglacial A and on the other hand the Pleniglacial B/Late Glacial. Both cycles show a striking resemblance as to their succession of the sedimentation phases, although they are widely differing by the texture of the sediment and the mode of sedimentation, due to the prevailing climatic conditions within each period.

The *cryoturbated soil horizon* being the equivalent of the Paudorf interstadial and separating the two cycles, ranks then as a very important bench mark in the field.

Based on this bi-cyclic sedimentation, the bipartitional subdivision of the Weichsel is a most adequate one for field-stratigraphical investigation in the periglacial area. It is also a point of departure for the study of the geomorphological phases that occurred during this period.

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It is clear now that, besides important aggradation, intensive erosion was active in all the valley systems of Belgium during the Eem period and that it contributed highly to the fixation of the now existing hydrographic network. With respect to this, the problem of the age of the Scheldt at Antwerp found a satisfying solution during our investigation. It lies beyond any doubt now that the origin of this branch of the Scheldt also goes back as early as the Eem period. This is an important statement for instead of putting forward the hypothesis of a Boreal incision (R. TAVERNIER, 1946) the question must be inverted: why did the Scheldt at Antwerp remained open for drainage towards the sea after its colmatation since the Eem? This problem then deals directly with the sedimentation phases during the Weichsel.

We often mentioned earlier the regional variations as to the mode of sedimentation throughout the Eem and Weichsel periods according to prevailing palaeoclimatical conditions. But, it seems also that these environmental processes differed greatly even within a particular sedimentation belt. So we noticed first the difference in composition and thickness between the entire sequences of Weichselian deposits in the Lys valley immediately north and south of the Flemish Hills (transitional area) and second between the Weichselian deposits of the Flemish Valley and the Scheldt at Antwerp (coversand area). From this it follows that each sedimentation belt was bound to local conditions and this to a much greater extent than has previously been thought. Therefore we think that a great deal of the Weichselian deposits were derived from the immediate vicinity, a statement which is supported by the nature of the enclosed Tertiary elements.

The most important sedimentation dates from the Pleniglacial A phase and more especially from the period of the *peaty loam formations.* Indeed, we could see at many places that whereas valley forms are still more or less well pronounced at the end of the *loams and coarse sands* period (and which the development of *desert pavement 1* was not capable to smoothen completely), at the level of the *cryoturbated soil horizons*, distinction between valley and plateau limits are difficult. This is due both to the considerable reduction in height between the valley bottom and the plateau tops and to the broad lateral extension of the *peaty loam formations*, running over the plateau top in many places.

It is obvious that at that time the previous existing water-courses must have lost almost completely their pattern especially since we also know that real fluviatile activity was reduced and dominated by solifluction.

Hereafter, during the Pleniglacial B, the drainage network was even more reduced and local melt water flows amidst an eolian sedimentation are the only evidence of fluviatile activity which subsisted. The latter was not capable to erode deeply so that the relief remained mainly as it occurred at the end of the Paudorf interstadial. Moreover, its flattening was continued at the time *desert pavement 3* developed and all fluviatile activity had stopped.

After the Weichsel period and maybe already at the end of it, the drainage system was faced with a flat relief and had the choice to redetermine its course. We could observe that not always the deepest (Eemian) erosion troughs were taken over again: in the Lys valley, around Courtrai, deep gullies (30 m and more) are situated west of the present course which flows on a less deep-going Late Pleistocene sequence; also in the Flemish Valley, the Late Pleistocene attains a greater depth and is much thicker than the Scheldt valley at Antwerp. In all these places, we now know that this is greatly due to the thickness of the *peaty loam formations* so that we have good reason to believe that if for some or another reason these deposits developed more faintly, the post-Weichsel relief in such places, at least within flat regions, presented a depressionlike topography. Consequently, the latter has been chosen by the streams, whereafter renewed incision at these places may haven taken place during the Holocene.

BIBLIOGRAPHY

ANDERSSON, J.A., Solifluction, a component of subaerial denudation (*Journ. Geol.*, 14, pp. 91-112, 1906).

BÉTHUNE (de), P., La coupe des briqueteries de la Plante (*Bull. soc. belge* de *Géol.*, 59, pp. 275-280, 1950).

BORDES, F.:
1) Stratigraphie des Loess et Evolution des industries paléolitiques dans l'Ouest du Bassin de Paris (*L'Anthropologie*, 56, pp. 1-30, 1952).
2) Les limons quaternaires du Bassin de la Seine (*Arch. Inst. Paléont. hum.*, Mém. n° 26, 472, 1954).

BRUNNACKER, K., Die Geschichte der Böden im Jüngeren Pleistozän in Bayern (*Geologica Bavarica*, 34, 1957).

BRYAN, Kirk:
1) Cryopedology. The study of frozen ground and intensive frostaction with suggestions on nomenclature (*American Journal of Science*, vol. 244, pp. 622-642, sept. 1946).
2) The geologic implications of Cryopedology (*Journal of Geology,* Chicago, vol. 57, nr. 2, pp. 101-104, 1949).
3) The erroneous use of Tjaele as the equivalent of perennially frozen ground (*Ibid.*, vol. 59, january, pp. 69-71, 1951).

BÜDEL, Julius:
1) Eiszeitliche und rezente Verwitterung und Abtragung in ebenfalls nicht vereisten Teil Mitteleuropas (*The Geographical Journal,* London, vol. 91, nr. 1, pp. 62-63, 1938).
2) Die Klimaphasen der Würmeiszeit (*Die Naturwissenschaften*, XIX, pp. 438-449, 1950).
3) Klima-morphologische Beobachtungen in Süditalien (*Erdkunde*, Bd V, Lfg. 1, Bonn, 1951).
4) Periodische und episodische Solifluktion im Rahmen der klimatischen Solifluktionstypen (*Ibid,* Band XIII, Lfg. 4, Bonn, 1959).
5) Die Gliederung der Würmkaltzeit (*Würzburger Geogr.* Arb. 8, 1960).

COMMONT, V., « La Chronologie et la Stratigraphie des dépôts quaternaires dans la vallée de la Somme » (*Ann. Soc. géol. de Belgique,* 39, pp. 156-170, 1911).

CORNET, J.:
1) Limon hesbayen et limon de la Hesbaye (*Ann Soc. géol. de Belgique*, 27, pp. 101-103, 1900).
2) La solifluction (*Ann. Soc. géol. du Nord*, 45, pp. 275-282, 1923).
3) *Leçons de Géologie*, Lamertin, Bruxelles, 1927.

CZERWINSKY, J., Structures périglaciaires en Basse-Silésie (*Bull. pérygl.* n° 14, pp. 158-167, 1964).

DOSTOVALOV, B.N.:
1) Physical conditions of the origin of frost fissures and of the development of fissure ice in loose rocks (*Akad. Nauk*, U.S.S.R., 1952).
2) Tetragonal systems of ice and soil veins in loose rocks, Perigl. Phenom. on the territory of the U.S.S.R., Moscow, 1960.

DYLIK, J., Problems of ice-wedge structures and frost-fissure polygons (*Bull. pérygl.* n° 15, pp. 241-291, 1966).

FINK, Julius:
1) Studien zur absoluten und relativen Chronologie der fossilen Böden in Österreich I : Oberfellabrunn (*Archæoligia Austriaca*, 25, S. 35-73, 1959).
2) Studien zur absoluten und relativen Chronologie der fossilen Böden in Österreich II : Wetzleinsdorf und Stillfried (*Ibid.*, 31, S. 1-18, 1962).
3) Die Boden Niederösterreichs (*Jahrbuch für Landeskunde von Niederösterreich*, Folge XXXVI, 1964).
4) Die Gliederung der Würmeiszeit in Österreich (*Report on the VIth International Congress on Quaternary*, Warsaw, 1961, vol. IV: Symposium on Loess, 1964).
5) Die Subkommission für Lösstratigraphie der Internationalen Quatärvereinigung (*Eiszeitalter und Gegenwart*, Band 15, pp. 229-235, 1964).
6) The Pleistocene in Eastern Austria (*The Geological Society of America*, Special Paper, 84, 1965).

FRECHEN, J. und ROSAUER, E.A., Aufbau und Gliederung des Würm-Löss Profiles von Kärlich im Neuwieder Becken (*Fort-schr. d. Geol. v. Rheinld. u. Westfal,*, 4, pp. 267-282, 1959).

FRENZEL, B.:
1) Uber die offene Vegetation der Letzten Eiszeit am Östrande der Alpen (*Verhandlungen der Zoölogisch-Botanischen Gesellschaft in Wien*, Band 103 und 104, 1964).
2) Zur Pollenanalyse von Lössen (*Eiszeitalter und Gegenwart*, Band 15, S. 5-39, 1964).

GALLWITZ, H., Eiskeile und glaziale sedimentation (*Geologica*, 2, pp. 1-24, 1949).

GOZDZIK, J.S., L'étude de la répartition topographique des structures périglaciaires (*Bull. pérygl.* n° 14, pp. 215-249, 1964).

GULLENTOPS, F.:
1) Quelques dépôts d'éboulis ordonnés (*Bull. soc. belge Géol.*, pp. 124-130, 1961).
2) Contributions à la chronologie du Pleistocène et des formes du relief en Belgique (*Mém. Inst. Géol. de Louvain*, t. XVIII, pp. 125-252, 1954).
3) Stratigraphie du Pléistocène supérieur en Belgique (*Geologie en Mijnbouw*, nr. 7, nieuwe serie, XIX[e] jaargang, blz. 305, 1957).

GULLENTOPS, F. and MULLENDERS, W., Evolution de la végétation et de la plaine alluviale de la Dyle, à Louvain, depuis le Pleni-Würm (*Ac. Roy. de Belg.*, 1, 1), pp. 1123-1137, 1956).

HAASE, G., Stand und Probleme der Lössforschung in Europa (*Geogr. Ber.*, H. 27, S. 97-129, 1967).

HÖGBOM, B., Über die geologische Bedeutung des Frostes Uppsala Univ. (*Geol. Inst. Bull.*, 12, p. 308, 1914).

JAHN, A. and CZERWINSKI, J., The role of impulses in the Process of periglacial soil structure formation (*Acta universitatis Wratislaviensis*, nr. 44, *Studia Geograficzne*, VII, 1965).

JANEKOVIC, Gj., Spezielle Bodenbildungen Jugoslawiens (*Pedologie*, XIV, 1, S. 85-103, 1964).

LADRIÈRE, M., Notes pour l'étude du terrain quaternaire en Hesbaye (*Ann. Soc. géol. du Nord*, 19, pp. 339-344, 1891).

LEFFINGWELL, E., Ground-ice wedges. The dominant form of ground-ice on the North coast of Alaska (*The Journal of Geology*, 23, p. 635-654, 1915).

LIEBEROTH, I., Löss sedimentation und Bodenbildung während des Pleistozäns in Sacksen (*Geologie*, Jg 12, pp. 149-187, 1963).

MAARLEVELD, G.C., Periglacial phenomena in the Netherlands during different parts of the Würm time (*Bull. perygl.*, nr. 14, pp. 251-256).

MACAR, P. et W. VAN LECKWIJCK, Les fentes à remplissage de la région liégeoise (*Ann. géol. de Belgique*, t. LXXXI, pp. B. 359-407, 1957-1958).

MANIL, G.:
1) Le quaternaire des environs de Gembloux. La tranchée de Mazy (*Bull. soc. Belge de Géol.*, t. LVIII, 1949).
2) Quelques considérations générales sur la stratigraphie quaternaire et la pédogénèse à propos de la description de trois coupes de Loess (Hesbaye gembloutoise) (*Ann. Soc. Géol. de Belgique*, t. LXXV, pp. 153-167, 1952).
3) Quelques types spéciaux de paléosols et leur importance géomorphologique (*Ibid.*, *Soc. géol.*, t. LXXVII, pp. 289-296, 1954-1955).
4) Observations macromorphologiques, microscopiques et analytiques sur le remplissage des fentes de gel (*Ibid.*, *Soc. Géol.*, t. LXXXI, pp. 409-421, 1957-1958).
5) Observations sur le remplissage des fentes de gel. In « Le Périglaciaire Pré-Würmien » (*Congrès et Colloques Univ. de Liège*, vol. 17, Liège, 1960).

MARÉCHAL, R., L'étude des phénomènes périglaciaires en Belgique (*Biul. Perygl.* nr. 4, pp. 83-98, 1956).

MARÉCHAL, R. and MAARLEVELD, G., L'extension des phénomènes périglaciaires en Belgique et aux Pays-Bas (*Meded. Geol. Stichting*, NS. 8, pp. 78-86, 1955).

MÜLLER, S.W., Permafrost or permanently frozen ground and related engineering problems (*Strategic Engineering Study*, nr. 62, Mil. Intelligence Div. Chief Engrs., U.S.A. and printing, 231, p. 1945).

PAEPE, R.:
1) Bijdrage tot de kennis van de bodemgesteldheid van de Zandleemstreek (Thesis, unpublished, p. 45, 1959).
2) Bouw en Oorsprong van de Vlakte van de Leie (Ph. D. Thesis, unpublished, p. 225, 1963).
3) Les dépôts quaternaires de la plaine de la Lys (*Bull. Soc. Belg. de Géol.*, t. LXIII, fasc. 3, pp. 1-39, 1964).
4) In VANHOORNE, R., Stratigraphy of the River Scheldt and stratigraphy of the Flemish Valley (*IInd International Conference on Palynology*, Livret quide, Utrecht, pp. 1-17, 1966).
5) On the presence of *Tapes senescens* in some borings of the coastal plain and the Flemish Valley of Belgium (*Bull. Soc. Belge de Géol.*, t. LXXIV, f. 2, 1965, pp. 1-5).
6) Comparative stratigraphy of Würm Loess deposits in Belgium and Austria (*Bull. Soc. Belge de Géol.*, 1966).

PAEPE, R. and LOUIS, A., Invloed van de Niveo-fluviale afzettingen op de bodemtextuur in de Zandleemstreek (*Pedologie*, t. XI, 1, 1961, pp. 49-60).

PAEPE, R. and VANHOORNE, R., The Eemian age of the river Scheldt at Antwerp (Belgium), in press, 1967.

PÉCSI, MARTON, Chronological problems of the Patterned Soils (*Biul. Perygl.*, nr. 14, pp. 279-293, 1964).

PÉWÉ, T.L.:
1) Sand Wedge Polygons (Tesselations) in the Mc Murdo Sound Region, Antarctica. A Progress Report (*American Journal of Science*, vol. 257, october, pp. 545-552, 1959).
2) Age of Moraines in Victoria Land, Antarctica (*Journal of Glaciology*, vol. R., nr. 31, March 1962).
3) Ice-wedges in permafrost Lower Yukon River near Galena, Alaska (*Biul. Perygl.*, nr. 11, 1962).
4) Paleoclimatic Significance of fossil ice wedges (*Biul. Perygl.*, nr. 15, pp. 65-73, 1966).

ROHDENBURG, H., Eiskeilhorizonte in südniedersächsischen und nordhessischen Lössprofile (*Idem*, pp. 137-170, 1966).

ROHDENBURG, H. und MEYER, B., Zur Feinstratigraphie und Paläopedologie des Jungpleistozäns nach Untersuchungen an südniedersachsischen und nordhessischen Lössprofilen (*Mitt. Deutsch, Bodenk. Gesellschaft*, Bd. 5, pp. 1-135, 1966).

RUHE, R.V., Stone lines in soils (*Soil Science*, Vol. 87, nr. 4, pp. 223-231, 1959).

RUHE, R.V. and DANIELS, R.B., Soils, Paleosoils and Soil-horizon Nomenclature (*Soil Science Society of America. Proceedings*, Vol. 22, nr. 1, pp. 66-69, 1958).

RUTOT, A.:
1) Les origines du quaternaire de la Belgique, (*Bull. Soc. Belge de Géologie*, 11, pp. 1-140, 1897).
2) Essai sur les variations du climat pendant l'époque quaternaire en Belgique (*Postglaziale Klimaveränderungen*, Stockholm, pp. 35-47, 1910).

RUTOT, A. and VAN DEN BROECK, E., Note sur la nouvelle classification du terrain quaternaire dans la Basse et dans la Moyenne Belgique (*Bull. Soc. Malacologique de Belgique*, t. XX, pp. 3-7, 1885).

SCHEYS, G., Bijdrage tot de kennis van de Hagelandse bodems en hun produktiecapaciteit (Ph. D. Thesis, Louvain, 1955).

SCHÖNHALS, E., Über fossile Böden im nichtvereisten Gebiet (*Eiszeitalter und Gegenwart*, 1, pp. 109-130, 1951).

SELZER, G., Diluviale Lösskeile und Lösskeilnetze aus der Umgebung Göttingens (*Geol. Rdsch.*, 27, pp. 275-293, 1936).

SHUMSKIJ, P.A., SHVECOV, P.F., DOSTOVALOV, B.N., Les particularités de la prospection géologique et celle du génie dans les régions d'extension des formations filoniennes de glace (*Acced. Sci. U.R.S.S.*, Inst. V.A. Obrudrev d'étude des pergelisols, 58 p. [Tred. M. JAYET] 1955).

SOERGEL, W.:
1) Lösse, Eiszeiten und Paläolithische Kulturen, Eine Gliederung und Alterbestimmung der Lösse (Jena, p. 177, 1919).
2) Diluviale Eiskeile (*Zeitschr. d. Dtsch. Geol. Gesellsch.*, 88, pp. 223-247, 1936).

STEUSLOFF, U., « Periglazialer » Tropfen und Taschenboden (*Geol. jb.*, 66, 1952).

TAVERNIER, R.:
1) Kryoturbatieverschijnselen in Oost-Vlaanderen (*Nat. Wet. Tijdschr.*, jg. 22, pp. 153-158, 1940).
2) De kwartaire afzettingen van België (*Nat. Wet. Tijdschrift*, 25, pp. 121-137, 1943).
3) Phénomènes périglaciaires en Belgique (*Bull. Soc. Belge d'Etudes géogr.*, t. XVI, pp. 112-138, 1944-45).
4) Compte rendu de l'excursion conduite par A. HACQUART et R. TAVERNIER; Géologie des terrains récents (*Bull. Soc. Belge de Géol.*, pp. 452-478, 1946).
5) L'évolution du Bas-Escaut au Pleistocène supérieur (*Ibid.*, t. LV, fasc. 1er, 1946).
6) Les formations quaternaires de la Belgique en rapport avec l'évolution morphologique du pays (*Ibid.*, t. LVII, fasc. 3, 1948).
7) Le quaternaire in « Prodrome d'une description géologique de la Belgique », pp. 555-589, Liège, 1954).

TAVERNIER, R. and MARÉCHAL, R., De bodemassociatiekaart van België (*Nat. Wet. Tijdschr.*, jg. 41, 1959, pp. 161-204).

TAVERNIER, R. et DE HEINZELIN, J., Chronologie du Pléistocène supérieur, plus particulièrement en Belgique (*Geologie en Mijnbouw*, nieuwe serie, nr. 7, pp. 306-309, 1957).

TAVERNIER, R. and SMITH, G.D., The concept of Braunerde (Brown Forest Soil) in Europe and the United States (*Advances in Agronomy*, vol. IX, 1955).

TROLL, C.:
1) Structurboden, Solifluktion und Frostklimate der Erde (*Geol. Rundschau*, Bd. 34, pp. 546-672, 1944).
2) Tiefenerosion, Seiten erosion und Akkumulation der Flüsse im fluvioglazialen und periglazialen Bereich (*Geomorph. Studien, Machatschek-Festschrift*, Gotha, pp. 214-226, 1957).

VAN DER HAMMEN, Th.:
1) Late-Glacial flora and periglacial phenomena in the Netherlands (*Leidse Geol. Meded.*, vol. 17, pp. 71-183, 1951).
2) Dating and correlation of Periglacial deposits in Middle and Western Europe (*Geol. en Mijnb.*, N.S. vol. 14, 9, pp. 238-336, 1952).
3) A new interpretation of the Pleniglacial Stratigraphical sequence in Middle and Western Europe (*Geol. en Mijnb.*, N.S. jg. 19, 12, pp. 493-498, 1957).
4) The Stratigraphy of the Late-Glacial (*Geol. en Mijnb.*, N.S., jg. 19, pp. 250-254, 1957).

VAN DER HAMMEN, Th., MAARLEVELD, G.C., VOGEL, J.C. and ZAGWIJN, W.H., Stratigraphy, climatic succession and radiocarbon dating of the Last-Glacial in the Netherlands (*Geol. en Mijnb.*, jg. 46, 3, pp. 79-95, 1967).

ZAGWIJN, W.H.:
1) Vegetation, climate and time-correlations in the Early Pleistocene of Europe (*Geologie en Mijnbouw*, N.S., jg. 19, pp. 233-244, 1957).
2) Vegetation, climate and radiocarbon datings in the Late Pleistocene of the Netherlands. Part I: « Eemian and Early Weichselian » (*Memoirs of the Geological Foundation in the Netherlands*, Nieuwe serie, nr. 14, pp. 15-45, 1961).

CHAPTER 2

THE VEGETATIONAL HISTORY OF THE LATE PLEISTOCENE (R. VANHOORNE)

2.1. INTRODUCTION.

Digging works executed for the construction of a tunnel under the river Scheldt at Antwerp and under the canal Ghent-Terneuzen at Zelzate as well as for the building of a quai-wall of the « Schepen Siffer » dock in the harbour of Ghent gave the opportunity to study deep sections in the Late Pleistocene deposits of Lower-Belgium, where generally there are no accessible pits consequently to the permanent high water level. Also clay pits gave us the possibility to examine important profiles. In these sections, several peat and peaty layers were discovered, the combined macroscopic and microscopic botanical study of which have been carried out. All the determinable macroscopic plant remains as leaves, seeds, fruits, oospores and megaspores, extracted from the plant-bearing sediments by washing, were counted and recorded in lists. Woods were also determined. The samples used for pollen analysis were treated chemically as follows:

- cold treatment with 70 % HF;
- boiling with 10 % NaOH after adding a pinch of Natriumperborate;
- acetolysis;
- mounting in glycerine gelatine jelly.

The percentages, represented on the pollen diagrams, are calculated on the base of a pollen sum, including the pollen of all the trees and the anemophilous herbs: *Gramineae, Cyperaceae, Ericales* and *Artemisia.*

Some samples were very poor in pollen. In order to give to each other the possibility to judge the statistical value, the accurate numbers of the counted pollen are added to the diagrams.

The investigations have been carried out in the palaeobotanical department of the Royal Belgian Institute of Natural Sciences and in the botanical laboratory of the State University Centre of Antwerp.

For description of the litho-stratigraphic units we refer to profile descriptions and drawings of R. Paepe (see chapter 1).

2.2. DESCRIPTION OF THE PALYNOLOGICAL DIAGRAMS AND THE MACROSCOPIC BOTANICAL STUDY.

2.2.1. The Transitional Area.

2.2.1.1. *The Sandloam Belt.*

Poperinge.

The microscopic botanical investigation of a peat layer at the base of the *loams and coarse sands* in the brickyard Schabalie at Poperinge allow us to draw a pollen diagram, which is represented in fig. 32. The dominant trees are *Betula* and *Pinus,* whilst *Corylus, Picea* and *Alnus* occur in very small quantities. The anemophilous herbs reach values situated between 37 % and 73 %. The percentages of the *Ericales* are very low. Amongst the more interesting recorded plants, the pollen of which is not included in the basic pollen sum, are *Ephedra* and *Linum.* Both are characteristic steppe elements. As these pollen grains are inbedded in real peat, reworking may be considered as excluded.

The general stratigraphy together with the pollen analytical features gave the possibility to date the peat layer as a deposit from the beginning of the Weichsel. The absence of great amounts of *Ericales,* the presence of which is considered by

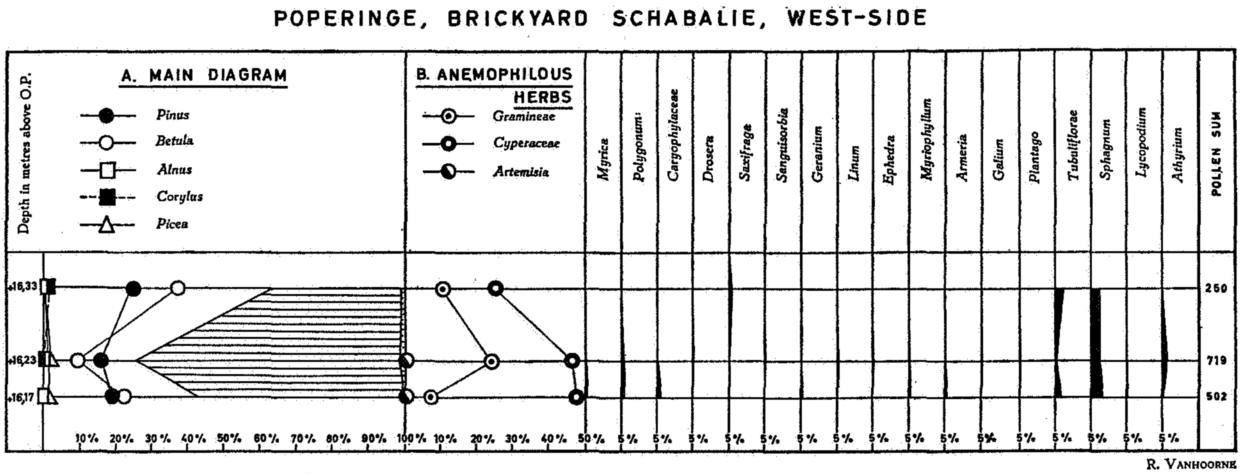

Fig. 32 — Pollendiagram of a peat layer, contemporaneous with the Warneton soil, at Poperinge.

W.H. ZAGWIJN (1961) as a characteristic feature of the first Weichsel stadial, exclude this period. Also the second Weichselian stadial is unlikely because *Salix* is not represented here. From the two remaining interstadials the Amersfoort-one is the most likely because we did not find high frequencies of *Picea*, which is striking in the Dutch diagrams for the Brørup interstadial. We conclude that the examined peat layer was formed in the Amersfoort interstadial, within which a forest steppe with *Betula* and *Pinus* covered the landscape. As the steppe elements are found in the middle of the diagram, which shows also an increase of the herbs, it might be that there was a fluctuation within this period from forest to steppe forest.

The macroscopic botanical study (Tab. 3) of the peat reveals the presence of marsh plants as *Comarum palustre* and *Carex*, which unfortunately cannot give any idea about the prevailing climate. The upper part of the peat seems to be deposited in dryer conditions than the base.

Absolute depth in metres	Fruits and seeds					Volume of washed material in litres
	Rumex sp.	*Lychnis Flos-cuculi* L.	*Hypericum* sp.	*Comarum palustre* L.	*Carex* div. sp.	
+16,45 -16,25	64	11	37		3	3,90
+15,65 -15,45					1	3,80
+15,45 -15,30		1		19	13	5,20

TABLE 3: *Vertical distribution of the quantities of macroscopic plant remains in a peat layer contemporaneous with the Warneton soil at Poperinge (brickyard Schabalie). Sample of upper layer taken between 6 and 7 m and these of the two lower layers between 12 and 14 m of right part of R. PAEPE's profile section.*

Rumbeke.

Three thin peaty layers, found in 1966 in the brickyard Demoulin at Rumbeke at the absolute depth of successively: 15,56-15,61, 15,87-15,90 and 16,12-16,20 m (see description of the section, R. PAEPE, fig. 11, p. 22), were examined pollen-analytically. The pollendiagram (fig. 33) shows a striking difference between the lower and the

0,00-1,80 m : Loamy sand with a recent soil on the top.

1,80-2,00 m : Cryoturbatic zone with sand, gravels and coarse grains of quartz.

2,00-5,50 m : Gray loam, showing a distinct stratification, caused by a repeated intercalation of thin, more sandy laminations.

RUMBEKE 1

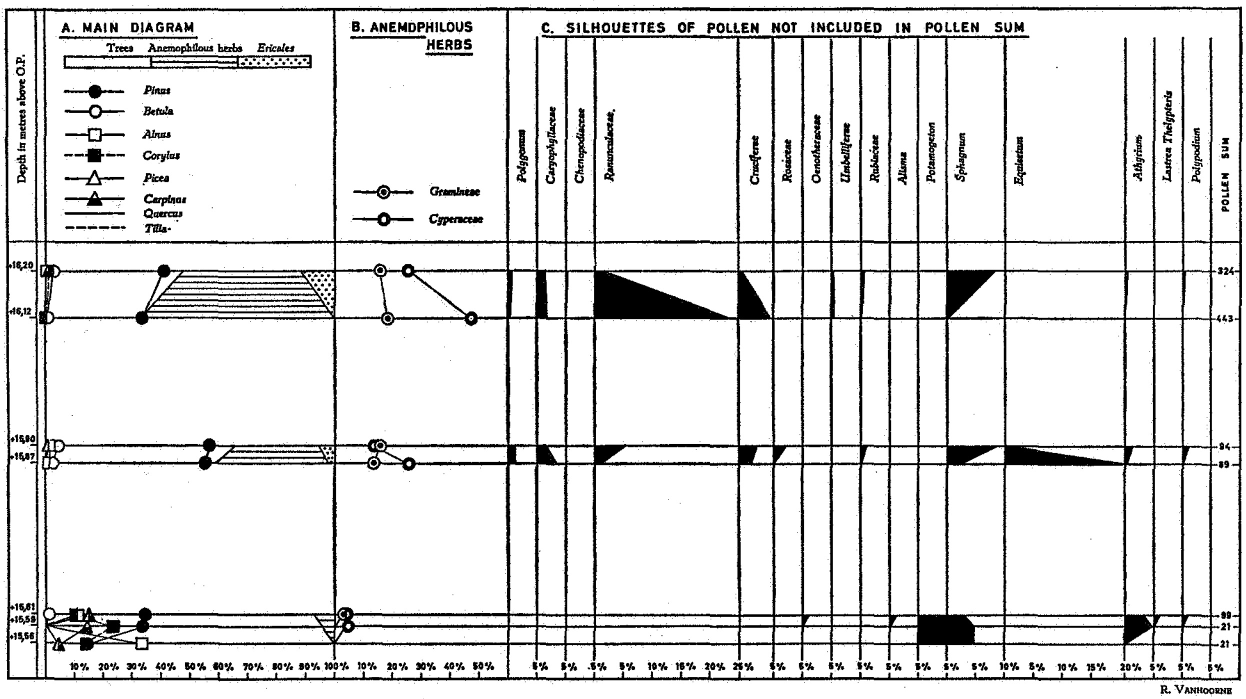

Fig. 33 — Pollendiagram of three superposed peat layers in the brickyard Demoulin at Rumbeke.

two upper layers. The lower one is characterized by relatively high percentages of thermophilous trees as *Tilia* and *Carpinus*, while the amounts of anemophilous herbs are very low. The pollen association *Carpinus-Picea*, occurring frequently in Belgian deposits from the Last Interglacial (R. VANHOORNE, 1957, 1963), points to an Eemian age of the lower peat layer at Rumbeke (*Rumbeke 2*, see R. PAEPE, this volume). The presence of *Carpinus* was confirmed by a macroscopic study of a peat bog, found in 1956 in the same clay-pit. Here follows the description of the section of the N-side of the clay-pit, where the peat was sampled in 1956.

5,50-6,40 m : Gray loam, including disturbed lenses of peat.

6,40-7,00 m : Clayey peat with a pebble band at the base.

7,00- : Blue Ypresian clay, showing a disturbed pattern along its top.

Between 5,50 and 6,60 m we could identify only some seeds of *Ranunculus sceleratus*. The base of the peaty deposit, however, yielded a richer flora, the elements of which are recorded in the following list (Tab. 4).

Plant names	Number of seeds and fruits
Potamogeton perfoliatus L.	21
Heleocharis cf. *palustris* (L.) R. BR.	1
Carpinus Betulus L.	34
Corylus avellana L.	3
Urtica dioeca L.	48
Stellaria holostea L.	1
Melandrium rubrum GARCKE.	27
Ranunculus Lingua L.	1
Ranunculus repens L.	6
Ranunculus sceleratus L.	1
Ajuga reptans L.	2
Stachys sylvaticus L.	111
	Number of catkins
Alnus glutinosa GAERTN.	1
	Leaved stems
Thuidium tamariscinum (HEDW.) BRUCK et SCHIMPER	1

TABLE 4: *List with the quantities of macroscopic plant remains from the Eem peat at Rumbeke (clay pit Demoulin).*

This plant association suggests a hornbeam forest with *Melandrium rubrum* and *Stellaria holostea* as characteristic plants, that grew on the higher parts of the alluvial plain, which seems to be in agreement with the profile (R. PAEPE, fig. 12).

In the two upper peaty layers, there is an increase of the anemophilous herbs, whilst *Pinus* becomes the dominating tree. Among the trees with low values, *Betula* is the best represented. These spectra point to an open, cold forest, within which the pine was the dominant tree. Although it may be considered as sure that these two upper layers are deposited at the beginning of the Weichsel pleniglacial phase (*loams and coarse sands*, see R. PAEPE), it is not easy to establish their exact stratigraphical place, because we do not dispose of a continuous diagram, showing the fluctuation of the different curves. The comparison however with the Dutch diagrams allow us to make some suppositions. It is possible that the middle peat layer developed in the Amersfoort interstadial and the uppermost one in the following stadial.

2.2.2. THE COVERSAND AREA.

2.2.2.1. *The Flemish Valley.*

Zelzate.

At the bottom of the tunnelpit at Zelzate, *peat and gravels* with great abundance of shells (*Cardium edule*, *Tapes senescens*, *Corbicula fluminalis*, etc.) cover the Tertiary Barton-clay (R. PAEPE, fig. 17; p. 25). In these beds occur locally gullies, filled up with plant remains. The palaeobotanical, macroscopic study of two of these gullies, situated at 11,5 m and 11,60-11,80 m below O.P., gave the possibility to make table 5, which shows a heterogeneous mixture of colder and warmer plants, belonging to a land- or a brackish and fresh waterflora.

This feature let us presume that these remnants come from plants, growing at the same time as the formation of the gullies or are reworked from older plant-bearing layers. A certain similarity with the plants found *in situ* in the Eemian at Ghent suggests that some of them are reworked from Eemian deposits, formed previously in the Flemish Valley. This supposition seems to be supported by the presence of *Brasenia schreberi*, which is a characteristic element of the Eemian flora of Western-Europe. Regarding to the plants with a cold character as *Selaginella selaginoides*, *Isoetes lacustris* and *Thalictrum alpinum* it is reasonable to admit that they are reworked from peat beds deposited in the very beginning of the Last Interglacial or even in the preceding ice age.

The megaspores of *Azolla filiculoides*, however, probably originate from the former interglacial. Indeed, these megaspores can be yielded from Elster-Saale peat beds, situated in the valley of the Scheldt at Melle, within which occurs *Azolla filiculoides* « in situ » (R. VANHOORNE, 1961).

The presence of *Corispermum hyssopifolium* and *Ruppia maritima* can be explained by the proximity of the seacoast.

Ghent.

The results of the macroscopic study of plant-bearing layers, found in 1949 in the upper sands during the digging works for the construction of the quai-wall of the « Sifferdock » at Ghent, are compiled in table 6.

ZELZATE - Tunnelpit

	Depth in metres below O.P.	11,5	11,6-11,8
Oospores	*Nitella* sp.		2
Oospores	*Chara* sp.		30
Mega-spores	*Selaginella selaginoides* LINK	1	2
Mega-spores	*Isoetes lacustris* L.		2
Mega-spo-rangia	*Azolla filiculoides* LAM.		2
Fruits and seeds	*Polygonum aviculare* L.	1	111
Fruits and seeds	*Caryophyllaceae*		1
Fruits and seeds	*Stellaria graminea* L.		1
Fruits and seeds	*Chenopodium album* L.		32
Fruits and seeds	*Corispermum hyssopifolium* L.		21
Fruits and seeds	*Thalictrum alpinum* L.		1
Fruits and seeds	*Thalictrum flavum* L.		4
Fruits and seeds	*Batrachium* sp.		34
Fruits and seeds	*Ranunculus Flammula* L.		9
Fruits and seeds	*Ranunculus repens* L.	2	191
Fruits and seeds	*Brasenia schreberi* J.F. GMEL.	2	
Fruits and seeds	*Ceratophyllum demersum* L.		8
Fruits and seeds	*Ceratophyllum submersum* L.		3
Fruits and seeds	*Rubus* sp.		8
Fruits and seeds	*Potentilla* sp.	2	5
Fruits and seeds	*Potentilla anserina* L.		26
Fruits and seeds	*Potentilla erecta* HAMPE	1	16
Fruits and seeds	*Prunus* sp.	2	
Fruits and seeds	*Viola* sp.	4	18
Fruits and seeds	*Myriophyllum alterniflorum* P. DC.		7
Fruits and seeds	*Myriophyllum spicatum* L.		14
Fruits and seeds	*Hippuris vulgaris* L.		14
Fruits and seeds	*Oenanthe aquatica* POIR.		1
Fruits and seeds	*Cornus sanguinea* L.	1	
Fruits and seeds	*Umbelliferae*		7
Fruits and seeds	*Empetrum nigrum* L.		1
Calyx tubes	*Statice Armeria* L.		18

	Depth in metres below O.P.	11,5	11,6-11,8
Fruits and seeds	*Menyanthes trifoliata* L.		12
Fruits and seeds	*Ajuga reptans* L.		3
Fruits and seeds	*Sambucus racemosa* L.		1
Fruits and seeds	*Cirsium* sp.		1
Fruits and seeds	*Alisma plantago* L.	1	9
Fruits and seeds	*Potamogeton* sp.	74	
Fruits and seeds	*Potamogeton* sp.		13
Fruits and seeds	*Potamogeton* sp.		360
Fruits and seeds	*Potamogeton* sp.		93
Fruits and seeds	*Ruppia maritima* L.		4
Fruits and seeds	*Zannichellia palustris* L.	1	19
Fruits and seeds	*Najas marina* L.		2
Fruits and seeds	*Juncus Gerardii* LOISEL.		3
Fruits and seeds	*Sparganium minimum* FRIES		3
Fruits and seeds	*Sparganium ramosum* HUDS.	9	9
Fruits and seeds	*Sparganium simplex* HUDS.		2
Fruits and seeds	*Scirpus lacustris* L.	24	289
Fruits and seeds	*Heleocharis* sp.		22
Fruits and seeds	*Cladium Mariscus* R.BR.	7	9
Fruits and seeds	*Carex* sp.		1
Fruits and seeds	*Carex* sp.	1	9
Fruits and seeds	*Carex* sp.		22
Fruits and seeds	*Carex* sp.	32	601
Fruits and seeds	*Carex pseudo-Cyperus* L.		3
Fruits and seeds	*Carex vesicaria* L.		23
Twigs and leaves	*Musci*		×
Shells	*Nummulites*	1	1
Shells	*Porifera*		×
Shells	*Ostracoda*		16
Shells	*Lamellibranchia*		×
Rests of insects		×	×
Volume of treated material in dm^3		2,45	5,10

TABLE 5: *Stratigraphical distribution of the numbers of the macroscopic plant remains found in the Eemian at Zelzate.* (× *means the presence.*)

	Depth in metres above O.P.	+ 4,00- 3,90	+ 2,60- 2,40	+ 2,30- 2,20
Oospores	*Nitella* sp.	11	—	20
	Chara spec. div.	27	—	20
Megaspores	*Selaginella helvetica* LINK	2	—	1
	Selaginella selaginoïdes LINK	77	—	13
Mega-spo-rangia	*Azolla tegeliensis* FLORSCH.	3	—	1
Fruits and seeds	*Potamogeton* spec. div.	5	2	8
	Carex spec. div.	3	1	13
	Scirpus cf. *caespitosus* L.	2	3	—
	Heleocharis cf. *palustris* R. BR.	—	—	1
	Caryophyllaceae	—	—	3
	Ranunculus Flammula L.	1	—	1
	Ranunculus Lingua L.	1	—	—
	Ranunculus sceleratus L.	—	—	1
	Batrachium sp.	5	5	29
	Rubus sp.	1	—	—
	Comarum palustre L.	—	1	2
	Myriophyllum verticillatum L.	—	—	1
	Menyanthes trifoliata L.	—	—	2
	Ajuga reptans L.	1	—	—
Leaves	*Salix herbacea* L.	28	50	200
	Salix herbacea var. *acutifolia* (?)	—	2	7
	Salix retusa L.	4	3	11

TABLE 6: *Vertical distribution and numbers of plant remains in peaty layers intercalated in eolian sands at Ghent (Sifferdock).*

The plant association in the examined levels at the absolute depth of + 4,00-3,90 m, + 2,60-2,40 m and + 2,30-2,20 m is characterized by the occurrence of the arctic-alpine willow *Salix herbacea* L., the alpine willow *Salix retusa* L. and two *Lycopodiaceae*, of which *Selaginella selaginoides* has a subarctic-subalpine distribution and *Selaginella helvetica* a subalpine one. The other plant remains mostly belong to a banal water and marsh flora without any climatic feature. *Azolla tegeliensis* FLORSCH. must be considered as reworked. The abundance of well preserved leaves of the mentioned, cold willows suggests that the deposits were formed under cold and wet conditions. R. PAEPE (fig. 19, p. 27) observed fluviatile layers in the same stratigraphic position in another section of the « Siffer dock » and therefore it may be concluded that these plant-bearing layers occur within the Pleniglacial B, more especially *coversand 1.*

The use of another building technique in the construction of the last part of the quai-wall was the reason that the recent excavation was much deeper than in 1949. On some places the greenish Paniselian sands *in situ* or reworked were reached so that the sections gave us the occasion to study the whole Late Pleistocene sequence.

On a few places we found a peat bog, established on the greenish Paniselian sands at the bottom of the Quaternary deposits (*peat and gravels*, fig. 19). That this peat has developed *in situ* was proved by the linked soil formation underneath and the roots penetrating from the peat in the underlying sand. The results of the macroscopic botanical study are recorded in tables 7 and 8. The most characteristic elements of the peat flora are *Brasenia schreberi* and *Aldrovanda vesiculosa*. The first mentioned plant is extincted in Europe since the Last Interglacial, while the second one has an actual distribution-area limited to Southern and Eastern Europe. Both species are frequent in Eemian deposits of Western Europe. The occurrence of seeds of these two plants in great quantities, the stratigraphical position, the palynological results (see later) and the palaeozoological data lead to the conclusion that the peat was deposited in the Last Interglacial.

Rumex Acetosella L.	1
Rumex maritimus L.	11
Rumex sp. (cf. *maritimus* L.)	44
Polygonum lapathifolium L. (small fruits)	125
Moehringia trinervia CLAIRV.	2
Chenopodium polyspermum L.	51
Chenopodium urbicum L.	11
Chenopodium sp.	4
Ranunculus sceleratus L.	1
Batrachium sp.	1
Brasenia schreberi J.F. GMEL.	125
Nymphaea alba L.	35
Ceratophyllum demersum L.	10
Ceratophyllum submersum L.	1
Hypericum cf. *acutum* MOENCH	14
Hypericum cf. *pulchrum* L.	57
Aldrovanda vesiculosa MONTI	23
Potentilla supina L.	22
Fragaria vesca L.	2
Calluna vulgaris HULL	2
Lysimachia cf. *vulgaris* L.	2
Mentha sp.	29
Lycopus europaeus L.	125
Alisma plantago L.	499
Potamogeton trichoides CHAM. et SCHLECHT.	17
Potamogeton sp. (cf. *trichoides* CHAM. et SCHLECHT.)	116
Najas marina L.	26
Najas minor L.	4
Najas flexilis (WILLD.) ROSTKOVIUS et SCHMIDT	19
Lemna cf. *gibba* L.	1
Sparganium simplex HUDS.	13
Sparganium minimum FRIES	1
Sparganium ramosum HUDS.	1
Scirpus lacustris L.	78
Cladium Mariscus R. BR.	4
Carex paniculata L.	1
Carex pseudo-Cyperus L.	4
Carex div. sp.	51
Nitella sp. (oospores)	∞ *
Chara sp. (oospores)	∞ *
Salvinia natans (L.) ALL. (megasporangia)	25
Leaves of moss	Several
Oligochaeta (coccons)	21
Ostracoda (shells)	39 half shells and two bivalve shells

TABLE 8: *Numbers of macroscopic organic remains found in a sample taken at the top of an Eemian peat layer* in situ *at the bottom of the Flemish Valley at Ghent (Sifferdock). Other organs than seeds and fruits are named.*

(*) More than five hundred.

Depth in metres below O.P.	Fruits and seeds																							
	Pinus silvestris L.	*Urtica dioeca* L.	*Rumex maritimus* L.	*Chenopodium album* L.	*Chenopodium urbicum* L.	*Ranunculus sceleratus* L.	*Batrachium* sp.	*Nymphaea alba* L.	*Ceratophyllum demersum* L.	*Ceratophyllum submersum* L.	*Aldrovanda vesiculosa* MONTI	*Rubus* sp.	*Prunus* sp. (?)	*Cornus sanguinea* L.	*Hydrocotyle vulgaris* L.	*Œnanthe* cf. *peucedanifolia* POLL.	*Ajuga reptans* L.	*Mentha aquatica* L.	*Mentha* sp.	*Lycopus europaeus* L.	*Eupatorium cannabinum* L.	*Alisma plantago* L.	*Potamogeton coloratus* VAHL.	*Potamogeton* div. sp.
8,90-9,00				1					15	1		1											2	2
9,00-9,10									20											1				
9,10-9,20					2			9	15	2					1		1			1				
9,20-9,30					19		1	19	44	24						1	4		1	1				1
9,30-9,40	4				40		1	67	68	151	2		1	3	1	4	11			30	2	1		2
9,40-9,50	4	2	5		25	2	2	19	15	24							2	1	2	16	1			1

Depth in metres below O.P.	Fruits and seeds												Wood				Shells of molluscs						Shells	Volume of washed material in litres
	Zannichellia palustris L.	*Najas marina* L.	*Najas minor* L.	*Najas flexilis* (W.) R. et SCHM.	*Juncus effusus* L.	*Lemna trisulca* L.	*Lemna* sp.	*Scirpus lacustris* L.	*Scirpus* div. sp.	*Cladium Mariscus* R.BR.	*Carex pseudo-Cyperus* L.	*Carex* div. sp.	*Pinus silvestris* L.	*Salix* sp.	*Alnus* sp.	*Quercus* sp.	*Theodoxus fluviatilis* LINN.	*Hydrobia stagnalis* BASTER	*Bithynia tentaculata* LINN.	*Lymnaea ovata* DRAP.	*Anisus albus* MÜLLER	*Anisus crista* LINN.	*Ostracoda*	
8,90-9,00	1	51															8	436	2	4		3	×	7,30
9,00-9,10		98	2														54	634	15	21		151	×	8,25
9,10-9,20		74	10					8				2					2	53	13	18	5	67	×	7,15
9,20-9,30		47	2	1			1	1			1	6	×	× ?		×						1	×	7,55
9,30-9,40		49	7		19	1	2	6	5	1	6	5	×			×								5,35
9,40-9,50		22			7	2	7		1		2	18	×		× ?									3,20

TABLE 7: *Vertical distribution and numbers of plant and animal remains occurring in an Eemian peat layer, developed* in situ *at the bottom of the Flemish Valley at Ghent (Sifferdock). (× means the presence).*

By overlooking table 7, it is striking that wood only has been found in the lower part of the peat layer, while the upper part contains a lot of shells of watermolluscs. This phenomenon suggests that the water level gradually raised during the growth of the peat bog.

These peat deposits are truncated at the top and in one place they are overlaid by gravels with shells, in which gullies with plant remains occur. We examined the material filling up two gullies (tab. 9), which were superposed in the immediate neighbourhood of the peat bog *in situ*, and of another plant-bearing bed situated at about thousand metres to the South (tab. 10). In

Chara sp.	5	Oospores
Ranunculus sceleratus L.	1	Fruits and seeds
Batrachium sp.	1	
Eupatorium cannabinum L.	1	
Potamogeton div. sp.	9	
Ruppia maritima L.	1	
Scirpus lacustris L.	3	
Scirpus sp.	3	
Cladium Mariscus R. BR.	1	
Carex div. sp.	6	
Hydrobia stagnalis BASTER		Shells of molluscs
Hydrobia ulvae PENNANT		
Bithynia tentaculata LINN.		
Ostracoda	1	Shell

TABLE 10: *List of macroscopic remains occurring in plant-bearing beds of Eemian age at Ghent (Sifferdock).*

both we discovered a mixture of plant remains and shells of fresh water molluscs, most of which were found in the peat bog *in situ*, together with organic remnants of organisms, living in brackish water. This observation joint to the presence of a lot of reworked peat blocks in the gravels leads to the conclusion that the greater part of the peat, which was originally deposited at the bottom, was taken away by streaming water, entering in the Flemish Valley in consequence of the raising sea-level during the transgression of the Last Interglacial.

The pollendiagram of this peat bog *in situ* (fig. 34) shows a predominance of *Pinus* in the lower part, while in the upper part *Quercetum mixtum* dominates. *Myrica*, not included in the pollen sum, attains high values at the top. According to W. ZAGWIJN (1961), who found a similar evolution at the base of the Eemian in the Netherlands, the lower part is placed in the zone E2 and the upper part in the zone E3. No subzones could be distinguished here. The very beginning of the interglacial, characterized by a vegetational development with *Betula* and *Pinus*, few herbaceous pollen and no thermophilous trees, is lacking here (zone E1).

Stratigraphically above this peat but at a higher depth, thin, peaty layers alternate with thin sand layers (middle part of the *peat and gravels;* bed 22, fig. 19). The spectra, yielded by the peaty laminations, gave the pollendiagram, which is represented in fig. 35. It shows a dominance mostly of *Pinus*, but also of *Alnus* and once of *Corylus*. However, the most characteristic elements are *Carpinus* and *Picea*, which occur practically at all the levels and point to an Eemian age. In comparison with the Dutch diagrams (W. ZAGWIJN, 1961) we put this peaty complex in the E5 zone. The appearance of *Fagus* in the middle of the diagram was extremely surprising, because the opinion prevails that this tree was absent in Western Europe during the whole Pleistocene and came back only late in the Holocene. The presence of pollen grains of the beech on several levels leaves no more doubt that this tree occurs in the Belgian Eem, which confirms the discovery of A. PASTIELS (1942) who found a nut, buds and woods of *Fagus* at Hofstade in the Mosean, which contained *Corbicula fluminalis* and must be reported to the Eemian.

2.2.2.2. *The Scheldt Valley.*

Antwerp (Dry Dock and Tunnelpit).

Plant-bearing beds, visible in the section of the dry dock and the tunnelpit on the left bank of the Scheldt at Antwerp, belonging to the *peat and gravels* and filling up a ravination in the Boom clay (Rupelian) (R. PAEPE, p. 29, fig. 25, 26, bed 9), contain a lot of macroscopic plant remains as seeds, fruits, cones, woods etc., which are listed in tables 11, 12, 13 and 14.

TABLE 9: *Numbers of plant and animal remains found in two superposed gullies above the Eemian peat at the bottom of the Flemish Valley at Ghent (Sifferdock).*

10,30-10,45	10,10-10,25	Depth in metres below O.P.	
10	5	*Chara* sp.	Oospores
1		*Betula* sp.	Male catcin
2		*Alnus glutinosa* GAERTN.	Fruits and seeds
	1	*Corylus avellana* L.	
1		*Quercus Robur* L. (?) (cupule)	
	1	*Polygonum aviculare* L.	
	1?	*Chenopodium album* L.	
	1	*Chenopodium* sp.	
1		*Ceratophyllum submersum* L.	
2		*Rubus* sp.	
1		*Potentilla procumbens* SIBTH.	
1		*Cornus sanguinea* L.	
3	2	*Mentha* sp.	
3		*Lycopus europaeus* L.	
1		*Solanum nigrum* L. (?)	
5		*Eupatorium cannabinum* L.	
24	6	*Potamogeton* div. sp.	
9	3	*Ruppia maritima* L.	
56	4	*Zannichellia palustris* L.	
6	2	*Najas marina* L.	
1	1	*Najas minor* L.	
6		*Najas flexilis* (W.) ROSTKOVIUS et SCHMIDT	
9	3	*Sparganium ramosum* HUDS.	
4	3	*Scirpus lacustris* L.	
3		*Scirpus* sp.	
2	1	*Cladium Mariscus* R. BR.	
10		*Carex* div. sp.	
1	1	*Theodoxus fluviatilis* LINN.	Shells of molluscs
	2	*Hydrobia stagnalis* BASTER	
1	1	*Bithynia tentaculata* LINN.	
17		*Limnaea ovata* DRAP.	
49	34	*Cardium edule* LINN.	
1		*Macoma balthica* LINN.	
	3	*Scrobicularia plana* DA COSTA	
2	2	*Corbicula fluminalis* MÜLLER	
2	3	*Pisidium amnicum* MÜLLER	
2		*Amygdala senescens* COCCONI (= *Tapes sen.*)	
55	16	*Ostracoda*	Shells
5,60	4,20	Volume of washed material in litres	

GHENT, SIFFER DOCK

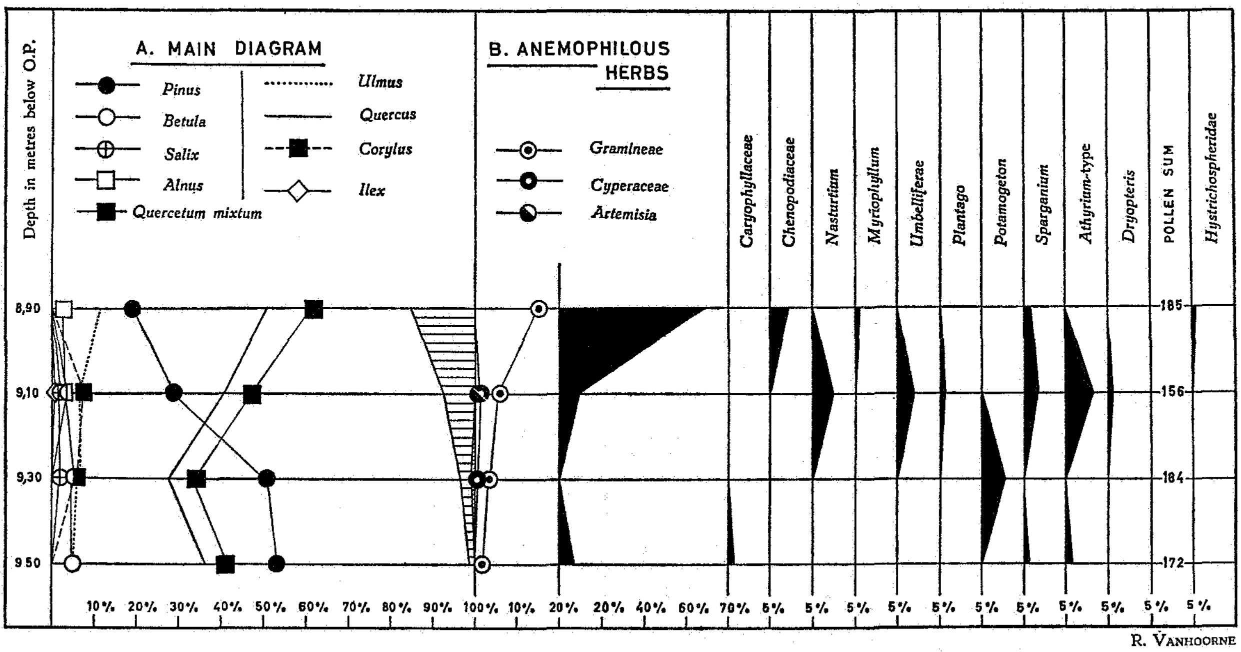

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Fig. 34 — Pollendiagram of the Eemian peat developed *in situ* on greenish sands at the bottom of the Flemish Valley at Ghent (Siffer dock). The first black silhouette represents the fluctuation of the percentages of *Myrica.*

GHENT, SIFFER DOCK

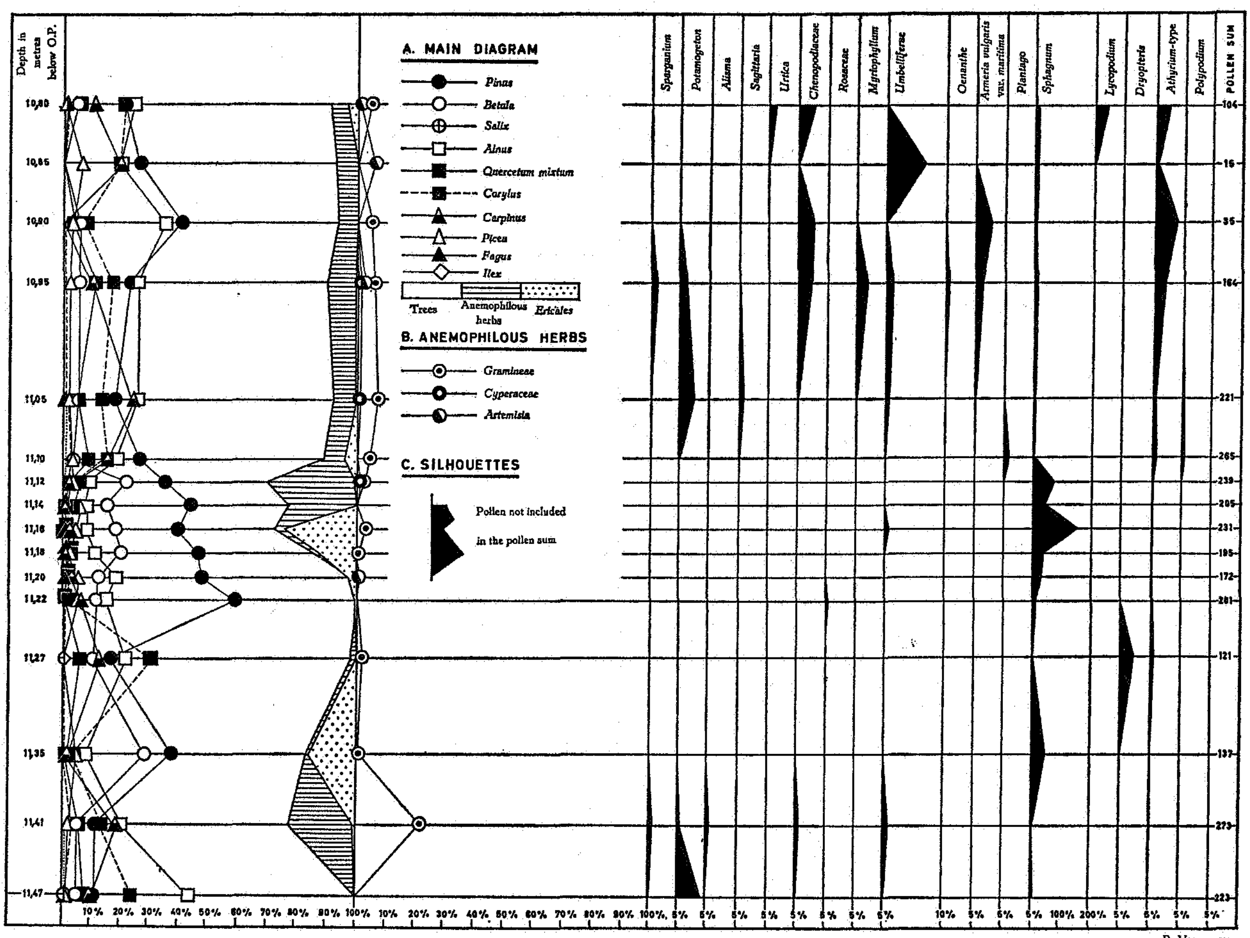

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Fig. 35 — Pollendiagram of thin, peaty layers, intercalated in sand at the bottom of the Flemish Valley at Ghent (Sifferdock).

Depth in metres below O.P.	5,84 - 5,96	5,96 - 6,08	6,08 - 6,20	6,23 - 6,30
Alnus glutinosa GAERTN.		8		
Corylus avellana L.		1		
Rumex obtusifolius or *crispus* L.		1		
Polygonum aviculare L.		2		
Chenopodium album L.	1		1	
Thalictrum flavum L.	2	3	1	
Ranunculus Lingua L.	1	1	3	
Ranunculus sceleratus L.	3			
Ranunculus Flammula L.	1	1		
Ranunculus repens L.		1		
Batrachium sp.	3	2		3
Nuphar luteum SIBTH. et SM.	13	11	2	2
Nymphaea alba L.		1	1	
Ceratophyllum demersum L.	1	4	3	
Potentilla argentea L.		1		
Potentilla anserina L.	1			
Mespilus monogyna ALL.		1		
Rhamnus frangula L.		2		
Viola sp.	2	1		
Elatine hydropiper L.			1	
Myriophyllum spicatum. L.	13	9	6	
Myriophyllum alterniflorum P. DC.	1	5		
Cornus sanguinea L.	2	2	1	1
Menyanthes trifoliata L.	6	12	1	
Lycopus europaeus L.		1		
Eupatorium cannabinum L.	2			
Potamogeton div. sp.	77	80	10	2
Najas marina L.			1	
Sparganium simplex HUDS.	4	2		
Sparganium ramosum HUDS.	12	11	1	1
Sparganium sp.	1			
Blysmus rufus LINK	2			
Scirpus lacustris L.	145	144	66	29
Cladium Mariscus R.BR.	2	4	4	1
Carex pseudo-Cyperus L.	2			
Carex div. sp.	44	41	9	6

TABLE 11: *Distribution and numbers of macroscopic plant remains in the peaty layers of Eemian age at Antwerp, dry dock (left bank of the river Scheldt).*

Chara div. sp.	41	Oospores
Polygonum aviculare L.	1	Fruits and seeds
Chenopodium urbicum L.	2	
Ranunculus Lingua L.	1	
Batrachium sp.	2	
Nuphar luteum SIBTH. et SM.	1	
Viola sp.	1	
Myriophyllum spicatum L.	3	
Menyanthes trifoliata L.	3	
Potamogeton div. sp.	12	
Sparganium ramosum HUDS.	1	
Scirpus lacustris L.	51	
Cladium Mariscus R. BR.	2	
Carex div. sp.	8	

Volume of washed material in litres: 3,28.

TABLE 12: *Quantities of macroscopic plant remains found in a gully of Eemian age in the dry dock at Antwerp (left bank of the Scheldt).*

Depth in metres below O.P.	*Pinus silvestris* L.	*Pinus* sp.	*Picea* sp.	*Salix* sp.	*Alnus* sp.	*Quercus* sp.	*Fraxinus* sp.
5,84 - 5,96	×	×		×	×		
5,96 - 6,08	×		×	×	×		×
6,08 - 6,20			×	×	×		×
6,23 - 6,30			×	×	×	×	

TABLE 13: *Woods found at different depths in the peaty gullies of Eemian age at Antwerp, dry dock (left bank of the river Scheldt).*

Alnus glutinosa GAERTN.	6
Alnus glutinosa GAERTN. (catkins)	24
Carpinus Betulus L.	5
Corylus avellana L.	1
Urtica dioeca L.	5
Polygonum aviculare L.	13
Chenopodium album L.	8
Ranunculus Lingua L.	3
Batrachium sp.	9
Brasenia schreberi J.F. GMEL.	1
Nuphar luteum SIBTH. et SM.	3
Nymphaea alba L.	1
Ceratophyllum demersum L.	2
Ceratophyllum submersum L.	1
Potentilla erecta HAMPE	2
Prunus avium L.	1
Viola sp.	10
Trapa natans L.	1
Myriophyllum alterniflorum P. DC.	4
Myriophyllum spicatum L.	1
Hippuris vulgaris L.	8
Cornus sanguinea L.	5
Œnanthe aquatica POIR.	2
Empetrum nigrum L.	18
Empetrum nigrum L. (leaves) (?)	9
Menyanthes trifoliata L.	2
Mentha sp.	3
Lycopus europaeus L.	1
Sambucus racemosa L.	3
Alisma plantago L.	5
Potamogeton trichoides CHAM. et SCHLECHT.	6
Potamogeton div. sp.	88
Zannichellia palustris L.	1
Sparganium ramosum HUDS.	20
Sparganium simplex HUDS.	3
Sparganium minimum FRIES	1
Scirpus lacustris L.	75
Cladium Mariscus R. BR.	11
Carex div. sp.	37
Stachys silvaticus L.	1
Nitella sp. (oospores)	1
Chara div. sp. (oospores)	91
Picea excelsa LINK (cones)	3

TABLE 14: *Numbers of seeds and fruits extracted from an Eemian gully in the tunnelpit on the left bank of the Scheldt at Antwerp. The name of other remains than seeds and fruits is mentioned after the plant-name.*

As these organic deposits cannot be considered as real peat bogs grown *in situ* but formed by accumulation of remnants coming from plants growing in the vicinity and floated together in gullies, the tables cannot give an idea of the ecological development of the site. Nevertheless, they are very important because they provide evidence for the age of the deposits. It is clear that a vegetation with *Carpinus Betulus*, *Quercus*, *Fraxinus*, *Mespilus monogyna* and *Cornus sanguinea*, pointing to a temperate climate, cannot be situated in a glacial or interstadial period. Moreover *Trapa natans*, no more belonging to the actual Belgian flora, has now a more Southern distribution area. Seeds of *Brasenia Schreberi*, a plant extincted in Europe at the end of the last interglaciation, and cones of *Picea excelsa*, a tree absent in the plains of Western Europe during postglacial times, suggest an Eemian age.

These Eemian sands including plant-bearing beds are stratigraphically overlain by a peat bog (*loams and coarse sand*, *Warneton soil*, R. PAEPE, p. 30, fig. 23 at 125 m), that yielded a flora, the elements of which are listed in table 15.

The most characteristic plant of this record is *Selaginella selaginoides*, a subarctic-subalpine ele-

Depth in metres below O.P.	Seeds and fruits													Leaves	Mega-spores
	Alnus glutinosa GAERTN.	*Urtica dioeca* L.	*Thalictrum flavum* L.	*Ranunculus Lingua* L.	*Batrachium* sp.	*Nuphar luteum* SIBTH. et SM.	*Ceratophyllum submersum* L.	*Hippuris vulgaris* L.	*Menyanthes trifoliata* L.	*Potamogeton* sp.	*Lemna* sp.	*Scirpus* sp.	*Carex* sp.	*Sphagnum* sp.	*Selaginella selaginoides* LINK
2,65 - 2,75									1						
2,75 - 2,80														1	1
2,80 - 2,85															
2,85 - 2,90				1					8						
2,95 - 3,05									27		5		11		
3,10 - 3,17						5		3	1		4	1	1		
3,17 - 3,25			3		1	3	1	1		1			1		
3,25 - 3,27	1	1													

TABLE 15: *Vertical distribution of the numbers of macroscopic plant remains in a peat bog of early Weichselian age at Antwerp, dry dock (left bank of the river Scheldt).*

ment belonging to the *Lycopodiaceae*. Most of the other elements are banal waterplants without any climatic feature. The pollendiagram of this peat bog shows a dominance of *Pinus* (fig. 36), the values of *Betula*, *Salix*, *Alnus*, *Corylus* and *Picea* being low. Anemophilous herbs reach a maximum of about 40 %. Mrs. LEROI-GOURHAN, who made a pollen analysis of two levels of this peat, got similar results. We are very grateful to Mrs. LEROI-GOURHAN, who communicated us kindly the following data.

Absolute numbers of pollen grains.

	Lower level	Middle level
Pinus	223	468
Salix	4	2
Alnus	3	—
Betula	10	14
Corylus	12	13
Artemisia	1	1
Gramineae	178	218
Cyperaceae	104	182
Chenopodiaceae	—	3
Thalictrum	9	1
Saxifragaceae	2	—
Leguminosae	1	—
Helianthemum	1	—
Œnotheraceae	—	1
Hedera	1	2
Umbelliferae	1	1
Rubiaceae	2	—
Boraginaceae	1	3
Labiatae	1	—
Chicoriaceae	1	2
Anthemideae	3	1
Liliaceae	—	1
Waterplants	58	30
Lycopodium	1	—
Equisetum	286	6
Polypodium vulgare	—	1
Monolete Ferns	6	8
Trilete Ferns	8	7

The macroscopic and microscopic analysis of this peat bog lead to the conclusion that the landscape was uncompletely covered by a forest with a cold character and within which *Pinus* was the very dominant tree. A comparison with the Dutch diagrams suggests that the peat bog was probably formed in the Amersfoort interstadial, which is considered by W.H. ZAGWIJN (1961) as the first, climatic amelioration in the

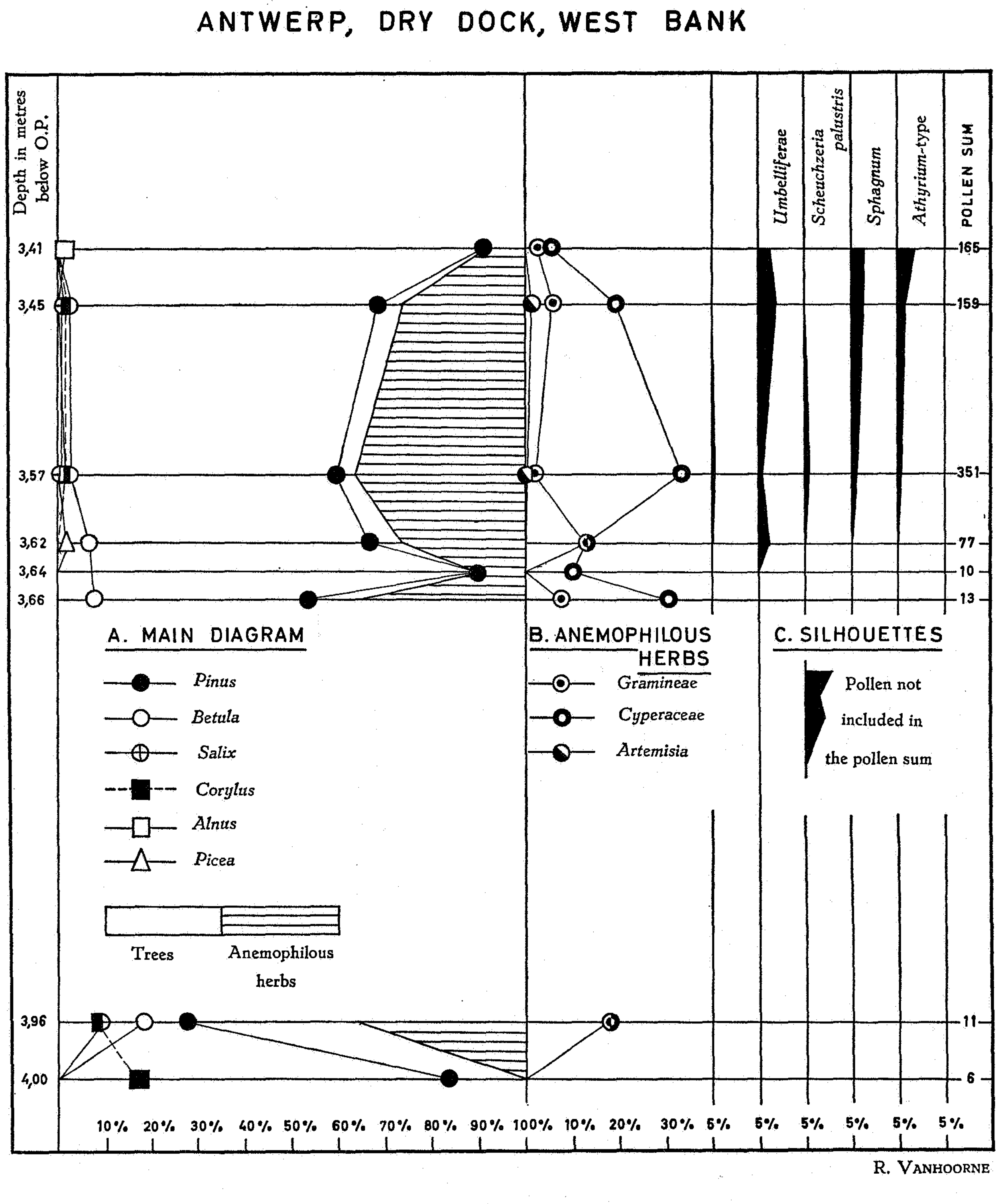

Fig. 36 — Pollendiagram of two superposed peat layers, formed in the beginning of the Weichselian, at Antwerp (dry dock, west bank). The first black silhouette represents the fluctuation of the percentages of *Polygonum*.

Weichsel, following the Eemian interglaciation. This warmer substage was also recognized in Denmark and named there the Rodebaek interstadial (Sv. Th. ANDERSEN, 1961). The Amersfoort interstadial has been dated about 64.000 y.B.P. in the Netherlands.

A macroscopic botanical study was also made of the peaty shell-bearing sediments, resting directly on the Boom clay in the dry dock but outside the ravination, filled up with Eemian deposits. We found a banal water- and marsh flora, recorded in tables 16 and 17, containing moreover stems of *Chara*, which unfortunately cannot give any idea about the prevailing climatic conditions.

Chara div. sp.	82	Oospores
Thalictrum flavum L.	2	Seeds and fruits
Batrachium sp.	32	
Nuphar luteum SIBTH. et SM.	6	
Myriophyllum alterniflorum P. DC.	1	
Hippuris vulgaris L.	20	
Oenanthe cf. *peucedanifolia* POLL.	2	
Lemna sp.	2	
Scirpus palustris L.	3	
Carex sp.	1	
Shells of water-molluscs		Several.

Volume of washed material in litres: 5,2.

TABLE 16: *Numbers of macroscopic remains found in a peaty, shell-bearing sediment resting on the Boom clay in the dry dock at Antwerp (left bank).*

Depth in metres below O.P.	Oospores	Fruits and seeds																		Ephippia	Shells	Volume of washed material in litres
	Chara sp.	*Rumex maritimus* L.	*Thalictrum flavum* L.	*Batrachium* sp.	*Nuphar luteum* SIBTH. & SM.	*Nymphaea alba* L.	*Ceratophyllum submersum* L.	*Comarum palustre* L.	*Viola* sp.	*Myriophyllum alterniflorum* P. DC.	*Myriophyllum spicatum* L.	*Hippuris vulgaris* L.	*Œnanthe* cf. *peucedanifolia* POLL.	*Menyanthes trifoliata* L.	*Potamogeton* div. sp.	*Lemna* sp.	*Sparganium simplex* HUDS.	*Scirpus lacustris* L.	*Carex* div. sp.	*Daphnia pulex*	*Molluscs*	
3,50–3,60	2				1					1				1				2	1			3,78
3,60–3,70			2		1			1	1			1		5				4	6			4,14
3,70–3,80					8	2						1		2			1?		6		×	3,95
3,80–3,90	5	1	4	2	17		1					1		1	3		1	1	1	1	×	4,10
3,90–4,00	6		1	12								4	1		1	6			2		×	2,85
4,00–4,10											1	2			3			2				3,30
4,10–4,20															1							3,20

TABLE 17: *Vertical distribution and numbers of macroscopic remains found in a peaty shell-bearing sediment resting on the Boom clay in the dry dock at Antwerp (left bank).* (× *means the presence.*)

For the sake of completeness, the study made by R. VANHOORNE in 1951 of the uppermost peat layer, is added. The pollendiagram, characterized by the predominance of *Quercetum mixtum* and *Alnus*, indicates that the peat started to develop at the end of the Atlantic period of the Holocene, just like the coastal peat in Belgium (F. STOCKMANS and R. VANHOORNE, 1954). The lack, however, of *Fagus* in the upper part suggests that the peat stopped here earlier than in the coastal plain, where the Dunkerkian Transgression puts an end to its development in the 4th century. The macroscopic research revealed that the peat at the base has developed in a brook forest, while the top contained a marsh vegetation, belonging to a *Magnocaricetum*. This evolution indicates a rise of the water-level.

The discovery of Eemian fluviatile deposits is very important for the age of the course of the Scheldt at Antwerp, which already existed in the last interglacial.

BIBLIOGRAPHY

ANDERSEN, Sv. Th., Vegetation and its Environment in Denmark in the Early Weichselian Glacial (Last Glacial) (*Geol. Surv. Denmark*, II S., Nr. 75, pp. 1-175, fig. 1-12, tabl. 1-33, pl. 1-15, Copenhague, 1961).

DE CONINCK, F., GREGUSS, P. et VANHOORNE, R., La superposition des dépôts tourbeux datant des oscillations Allerød et Bølling à Stabroek (Belgique) (*Pédologie*, XVI, 3, pp. 293-308, pl. I-IV, fig. 1-2, Gand, 1966).

PASTIELS, A., 1942 — Note sur la flore pléistocène d'Hofstade (Belgique) (*Bull. Mus. roy. d'Hist. nat. Belgique*, t. XVIII, n° 38, pp. 1-22, pl. I-III, Bruxelles, 1942).

STOCKMANS, F. et VANHOORNE, R., 1954 (avec la collaboration de C. VANDEN BERGHEN). Etude botanique du gisement de tourbe de la région de Pervijze (plaine maritime belge). (*Mém. Inst. roy. Sc. nat. Belgique*, n° 130, pp. 1-144, pl. I-IV, fig. 1-9, 1 carte au 1/20.000 — Bruxelles, 1954).

VAN DER HAMMEN, T., MAARLEVELD, G. C., VOGEL, J. C. and ZAGWIJN, W. H., 1967 — Stratigraphy, climatic succession and radiocarbon dating of the last glacial in the Netherlands. (*Geol. en Mijnbouw*, jg. 46, nr. 3, pp. 79-95, fig. 1-9, Rijswijk, 1967).

VANHOORNE, R., 1951 — Evolution d'une tourbière de plaine alluviale au Kruisschans (Anvers, Belgique). (*Bull. Inst. roy. Sciences nat. Belgique*, t. XXVII, n° 20, pp. 1-20, pl. I-IV, fig. 1-7 — Bruxelles, 1951).

VANHOORNE, Roger, 1957, Les flores pléistocènes belges (*Résumés des communications*, V^e Congrès intern. INQUA, pp. 189-190, Madrid — Barcelona, 1957).

VANHOORNE, R., 1961 — Evolution du paysage botanique en Belgique depuis le Pliocène jusqu'à l'époque romaine (*Ass. nat. Prof. Biol. Belgique*, Ann. 7, n^os 2-3, pp. 30-33, Halle, 1961).

VANHOORNE, R., 1963 — La tourbe fin Eémien et début Würm du plateau d'Oevel (Belgique) (*Bull. Inst. roy. Sc. nat. Belgique*, t. XXXIX, n° 14, pp. 1-7, fig. 1-2, Bruxelles, 1963).

VOGEL, J.C. and WATERBOLK, H.T., Groningen Radiocarbon, Dates V (*Radiocarbon*, Vol. 6, pp. 349-369, New Haven, 1964).

ZAGWIJN, W.H., 1961 — Vegetation, climate and radiocarbon datings in the Late Pleistocene of the Netherlands (*Mem. Geol. Found. Netherlands*, N.S., nr. 14, pp. 15-45, fig. 1-14, tabl. I-II, Photopl. 1-3, pl. I-VIII, Haarlem, 1961).

CHAPTER 3

GENERAL CONCLUSIONS (R. PAEPE and R. VANHOORNE)

The present study adds to the conclusion, already stated by R. TAVERNIER, that the Late Pleistocene in Belgium deals with the deposits of both Eem and Weichsel periods. Indeed the sedimentation areas of the Weichsel show a close relationship with those established during the Eem and a gradual transition of the lithological composition between the deposits could be observed.

The geographical subdivision into a loess, a transitional and a coversand area, can be followed throughout the sediment succession of the Eem and Weichsel combined. Indeed, the loess area commonly appears to be a sedimentation belt dominated by dry climatic conditions within which fluvial activity is rather scarce.

Against this stands the fluviatile activity which controlled the sedimentation and morphological shaping of the coversand area. The transitional area reveals to be then the place where both phenomena interfere in a delicate adjustment to each other.

The Eem period, at least for its maximum phase, is characterized by a slightly warmer climate than the present one. This is supported, palaeobotanically, by the occurrence in well developed peat bogs of *Brasenia Schreberi* and *Aldrovanda vesiculosa*. Besides, it is also sure now that *Fagus* belonged to the forest vegetation, composed of the actual existing trees in Belgium and of *Picea*.

In addition, the deeply eroded thalwegs filled usually with *peat and gravels* point to a concentrated evacuation of the superficial water with a high capacity to erode, a phenomenon which occurs only under a dense forest cover, implying also humid and warm climatic conditions. This is also supported by the fact that in the Northwestern part of the country, the *peat and gravels* reveal to be a marine (transgression) deposit containing *Tapes senescens* and then similar to the « Senescens Sande » of Northern Germany. Thanks to the immediate stratigraphical relationship that could be established between these marine Eemian facies and the *Rocourt soil* at Zelzate, the adherance of the Belgian periglacial area with Northern Europe is now evident.

The climatic transition from the Eem to the Weichsel period was not marked by an abrupt alteration but presumably by a gradual decay of the climate. So it can be explained that the *sands and gravels* show, to some extent, great affinity with the Eem deposits as to their lithological composition and also, that podzolic soil formation (*Antwerp soil*) was still possible. However, the announcement of the glacial period is reflected in the flatness of the valley forms (eventually underlain by thin frost wedges) but mostly in a widely lateral extension of a solifluction deposit debouching into these valleys.

Colder conditions were reached during the next sedimentation phase which is characterized by a gradual replacement of the coarse textured elements by finer one (*loams and coarse sands*) and furthermore by the strong influence of cryoturbatic-solifluction activity. Nevertheless, the after-effect of the favourable Eemian climatic conditions is still felt here by periodical improvements of the climate leading towards the development of peat and soil horizons. These warmer oscillations allow the establishment of open subarctic forest with *Betula* and *Pinus* within which a periodical extension of the steppe is proved by the occurrence of *Ephedra* and *Linum* and furthermore by an increase of the herbs. This botanical feature is also set forth by the development of one or more steppe soils to which the connotation *Warneton soil* complex was given and which shows a striking resemblance with the humic upper part of the Stillfried A in Austria.

Contrary to observations yielded from other countries, the difference between an Amersfoort and a Brørup interstadial can hardly be made, both lithostratigraphically and palaeobotanically. The lack of relatively high frequencies of *Picea* in the pollen diagrams, however, points more to a vegetational association found in the Amersfoort of the Netherlands and Denmark.

We prefer to omit the term « Early Weichselian » for these deposits which we are inclined to classify within the Pleniglacial because of the presence of numerous periglacial phenomena.

The above recorded gradual deterioration of the climate ends with the establishment of the *desert pavement 1* and finally of the *small frost wedge row.*

This first severe cold oscillation, was of short duration whereafter a new sedimentation similar to the one characterizing the *loams and coarse sands*, started. In fact, the *peaty loam formations* are considered as an acceleration of all the foregoing sedimentation cycles and at least four of them were recorded. This evolution is believed to be connected with an improvement of the climate, resulting in the development of important soil horizons as the *Poperinge* (45.600 y.B.P.) and the *Hoboken soil* (32.490 y.B.P.) and ultimately with the establishment of the *cryoturbated soil horizon* or *Kesselt-Zelzate soil* (28.200 y.B.P.) which is the equivalent of the Paudorf interstadial.

Whereas each of the cycles in the *peaty loam formations* ends with a faintly developed desert pavement (sometimes solely an eolian sand layer) and frost wedges, the same can be observed as a major phenomena at the top of the *cryoturbated soil horizon* called *desert pavement 2* and *fine frost wedge row.* Both the latter form the upper limit of the underlying cold deposits denominated (Weichsel) Pleniglacial A and introduce the following Pleniglacial B phase.

During the Pleniglacial B phase, the mode of sedimentation changes considerably, resulting in an important eolian activity leading to the building up of the coverloams and coversands. This is considered together with the occurrence of numerous frost wedges as due to generally colder and also dryer climatic conditions. Nevertheless, more humid conditions may have prevailed in the coversand area and to some extent also in the transitional area causing the formation of the *cross bedded sands* or fluviatile structures, at the base or as a lateral facies of both *coverloam 1* and *coversand 1.* This cold-humid character is supported by the existence of real tundra and alpine plants as *Salix herbacea* and *Salix retusa* found locally within peaty bands of the *coversand 1.* It may be that these peaty bands tally with loamy layers showing fluviatile structures, usually cryoturbated, observed within the bulk of the *coversand 1* in some places.

Hereafter, a new important climatic change caused the establishment of *desert pavement 3* followed by the *large frost wedge row* a feature generally observed in the three sedimentation areas. In our opinion, the latter corresponds then to the maximum cold of the Last Glaciation and stratigraphically with a considerable hiatus in the sedimentation sequence.

It is our conviction that sedimentation of the eolian deposits *coverloam 2* and *coversand 2* is due to a slight decrease of the previous severe cold-dry conditions. This is the reason why we are inclined to trace the upper limit of the Pleniglacial B at the top of these formations.

The stratigraphy of the Late Glacial finds its utmost expression in the coversand area where it starts with the appearance of a complex of well developed peaty or (fluviatile) loam bands. This implies an improvement of the climate which palynologically, was found to correspond with the Bølling oscillation (*Stabroek soil;* 12.300 y. B.P.).

In the very northern extension of the coversand area, peat layers, palynologically defined as Allerød, occur frequently.

A subdivision of the Late Glacial was sometimes possible in the transitional area too, thanks to the presence of sporadically occurring fine frost wedges or even, exceptionally a thin desert pavement separating at least two different late coversand deposits.

No definite traces of it were found, up to now, in the loess area.

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Overlooking the Weichsel stratigraphy in Belgium, we conclude that only two major sedimentation cycles occurred corresponding with widespread climatic oscillations.

The first one or Pleniglacial A, was characterized by a mainly fluvial-solifluction sedimentation under cold-humid conditions, while during the second one, comprising the Pleniglacial B and the Late Glacial, a cold-dry climate prevailed including principally eolian activity.

Notwithstanding these differences, the two cycles reveal to show an analogy in the succession of the sedimentation phases. In this view, both cycles start with a rather coarse sedimentation: on the one side, *sands and gravels* and *loams and coarse sands* and, on the other hand, *cross bedded sands* and *coverloam 1* or *coversand 1.* They represent the transition of warm, respectively the Eem and the Paudorf, to cold climatic conditions.

Next, in both cases, the coarse sedimentation is interrupted by a severe cold oscillation of the climate: *desert pavement 1* and *small frost wedge row* versus *desert pavement 3* and *large frost wedge row.*

Also, the sedimentation that followed on both cold phases, shows a remarkable resemblance: the *peaty loam formations* are considered as a recurrence system of the sedimentation prior to the cold oscillation and similarly, the quick succession of *coversand 2, late coversand 1* and *late coversand 2,* with intercalated peaty or humic beds, reveals the repeated sedimentation of *coversand 1.* It must be stated that in both cases the climate evolves gradually from severe cold to milder conditions leading respectively to the Paudorf and the Holocene.

As a result, a bipartition of the Weichsel Glaciation in Belgium is evident, the first part of which corresponds with the Pleniglacial A, while it is now obvious that the second part comprises the Pleniglacial B and Late Glacial combined.

From a geomorphological point of view, valley erosion was active during the Eem in all the actual existing drainage systems. The age of the Scheldt at Antwerp, a problem which lasted for several years, is found both on stratigraphical and palaebotanical grounds to date also back, at least from the Eem period.

Subsequent filling of the thalwegs is greatly due to the sedimentation during the Pleniglacial A, more especially to the sedimentation of the *peaty loam formations* at the end of which the landscape was characterized by a smooth relief. Both solifluction processes and local pediplanation played an important role. The Pleniglacial B inherited the pre-existing flat relief and reinforced its character as a result of dominantly eolian activity and important pediplanation (*desert pavement 3*).

The drainage system had to readjust its pattern upon the landsurface left by the Weichsel glaciation.

APPENDIX

DETAIL DESCRIPTION, BRICKYARD « POINT DU JOUR », TONGRINNE.

Fig. 2

Bed 1: Surface soil with Ap horizon (10 YR 4/3) in the upper part and a textural B horizon (B_2t) (10 YR 4/4) in the lower part.

Bed 2: Yellowish brown loam (10 YR 5/4) characterized by the alternation of fine loam and sand layers; numerous pores with clay coatings.

Bed 3: Cryoturbation horizon (10 YR 5/6) composed of alternating yellowish sandy and brownish loam strata; from the upper limit, large frost wedges may extend downwards; gleyification spots.

Bed 4: Gray brown (10 YR 4/4) homogeneous loam.

Bed 5: Gray heterogeneous loam (2.5 YR), with irregular stratification; locally very small frost wedges occur and also small pebbles are found within the bulk of this deposit; two oxydation zones, one situated in the middle and another at the base of the deposit are present; from the latter mentioned, medium size frost wedges extend downwards.

Bed 6: Dark yellowish brown (10 YR 4/4) homogeneous loam.

Bed 7: Yellowish gray (2.5 YR) loam, the upper part of which is rather humiferous and therefore slightly darker (10 YR 4/3) in colour; the lower part contains numerous Fe/Mn point concretions and vegetation remnants. A fine stratification is visible. Along the upper limit extends a pebble band composed of greenish phyllades and locally small frost wedges are observed too. The lower limit is ravinating the underlying deposits. Crotovines are commonly found at this level.

Bed 8: Reddish (7.5 YR 4/4), clayey loam, occasionally brown and then less clayey. Numerous sandy and lighter coloured crotovines. Threads composed of very red, heavy clay with capricious branchlike extension.

Bed 9: Brown, clayey loam with sandy, yellowish intercalated layers (10 YR 5/4).

DETAIL DESCRIPTION SANDPIT « VELLE », RACOUR.

Fig. 3

Bed 1: Ap-horizon.

Bed 2: Light yellowish brown (10 YR 6/4) loam; homogeneous.

Bed 3: Yellowish brown (10 YR 5/4) loam with calcareous concretions and with solifluction structures at its base.

Bed 4: Large frost wedge row with stoneline on top of it.

Bed 5: Alternating greenish gray sand and yellowish brown loam layers, becoming stratified brown sandloam occasionally with rocky elements at the base. Many fine frost wedges may occur in the bulk of the deposit.

Bed 6: Yellowish brown (10 YR 5/5) coarse sand, slightly cross-bedded; becoming more loamy and cryoturbated upwards.

Bed 7: Very fine frost wedge row developing from top of the underlying deposits.

Bed 8: Brown (10 YR 5/6) sandy loam highly disturbed by overlying penetrating frost wedge row (7); containing numerous disorderly spreaded stones and showing solifluction structures.

Bed 9: Constant small frost wedge row with stone line on top of it.

Bed 10: Cross bedded sands and gravels, occasionally with cryoturbated grayish sandloam beds in the top and base zones, underlain by a thick gravel bed while filling up shallow depressions. Locally worn reddish lumps of iron stained material occur.

Bed 11: Tongrian and Landenian sands separated by gravelly layers.

DETAIL DESCRIPTION OF BRICKYARD « DE STEENBERG », VOLKEGEM.

Fig. 4

Bed 1: Dark brown (7.5 YR 4/4) leached loam.

Bed 2: Brownish yellow homogeneous loam unleached, at the bottom slightly browner (2').

Bed 3: Yellowish brown (10 YR 5/6) loam mixted with reddish yellow sand and gray, humic lumps due to cryoturbation; sporadically small rolled sandstone fragments and a fine frost wedge row along the upper limit.

Bed 4: Quickly alternating yellowish loam with fine sand layers, numerous little frost wedges and sporadical sandstone fragments.

Bed 5: Sandstone pebble band along which frost wedges may occur; mainly composed of Paniselian sandstone debris.

Bed 6: Light yellowish brown (10 YR 6-5/4) leaf structured loam with brown sandy lenses and ferruginous clay breccia; the whole is highly cryoturbated and frost wedges occur.

Bed 7: Sandstone pebble band, mainly composed of Paniselian sandstone debris.

Bed 8: Tertiary substratum (Paniselian clayey sand) with weathering zone at the top.

DETAIL DESCRIPTION OF SLUICE EXCAVATION (Canal du Centre), MAISIÈRES.

Fig. 5

Bed 1: Rubble.

Bed 2: Gray sandy loam with calcareous concretions.

Bed 3: Yellowish sand and gray loamy sand intermixed in a cryoturbation pattern; leached.

Bed 4: Gray brown sand and gray sandy loam, intermixed in a solifluction pattern; unleached.

Bed 5: Yellowish brown sand; glauconiferous.

Bed 6: Olive (5 Y 5/3) homogeneous loam containing fine sandy layers.

Bed 7: Blueish clay with irregular structure.

Bed 8: Yellowish brown (10 YR 5/4) clayey loam alternating with fine yellowish sandy layers.

Bed 9: Gravel layer (stone line) composed of rolled chalk fragments; the lower limit coincides with a frost wedge row.

Bed 10: Cross bedded, yellowish sand containing gravelly lenses composed of rolled chalk fragments.

Bed 11: White gray medium coarse sand, becoming gravelly (chalk, phtanites) towards the base.

Bed 12: Sporadically occurring frost wedges.

Bed 13: Dark gray (5 Y 4/1) loam, highly calcareous.

Bed 14: Dark brown (10 YR 4/2) hydromorphous soil with rust spots and plant remains.

Bed 15: Yellowish brown (10 YR 5/4) loam.

Bed 16: Cretaceous chalk.

DETAIL DESCRIPTION BRICKYARD « DUMOULIN », WARNETON, EAST SIDE.

Fig. 6

Bed 1: Alluvial deposits with two subdivisions, consisting usually of grayish brown sandy clay.

Bed 2: Medium fine yellowish sand.

Bed 3: Large frost wedge row composed of wedges, pearlike and pocketlike structures filled with overlying sand (2).

Bed 4: Yellowish brown fine stratified loam with regular undulations fainting out gradually towards the bottom.

Bed 5: Yellowish brown fine stratified loam, equal to (4) but subhorizontally layered.

Bed 6: Same fine loam layers as above (4) and (5), but with irregular lenses and layers of cross bedded coarse sand and even gravel towards the bottom. The sand layers show an irregular upper limit composed of small apophyses pearcing into the intercalated loam layers (solifluction structure).

Bed 7: Fine frost wedge row filled with fine sand overlain by a stone line.

Bed 8: Quickly alternating sandy, loamy and clayey thin layers with solifluction structure (irregular upper limit characterized by small apophyses), The top of the sandy layers is often oxydized.

Bed 9: Humic horizon in the lower part of bed (8).

Bed 10: Stone line composed of small eolised flint stones in medium fine sand matrix. Sometimes overlain by thin, fluviatile structured, loamy deposit.

Bed 11: Small frost wedge row, locally growing out into larger syngenetic frost wedges.

Bed 12: Yellowish white fluviatile loam with cryoturbatic structures; at the base, a zone with mollusks.

Bed 13: Discontinuous frost wedge row.

Bed 14: Homogeneous yellowish (2.5 Y 7/6) loam.

Bed 15: Gray brown (10 YR 5/2) humic soil horizon, slightly calcareous and occasionally with peat lumps in sandy loam.

Bed 16: Grayish (2.5 Y 5/2) lower part of (15) with numerous reddish brown pipestems.

Bed 17: Blueish white gley horizon in heavy clayey loam; leached.

Bed 18: Reddish (7.5 YR 5/6 = strong brown) soil with numerous gley mottles and reddish pipestems; leached; in lowerlying depressions, becomes a bluegreen hydromorphous soil; leached.

Bed 19: Blueish green clayey loam with zones of calcareous concretions, becoming a gray brown sandloam towards the bottom, unleached.

DETAIL DESCRIPTION BRICKYARD « DUMOULIN », WARNETON, SOUTH SIDE.

Fig. 7

The numbers refer to the ones used for the east side section. Only laterally differing facies are considered here.

Bed 11: Small frost wedge row (west end) characterized by a reddish colouring (oxydation); towards the east, while situated off the underlying reddish soil, going over into cryoturbatic (humic) tonguing structures.

Bed 12: Yellowish and brown fluvial, undulating loam layers (*a*) (east end) laterally going over into a depression filling the topzone of which becomes increasingly humic (*b*) while the lower, highly cryoturbated part is a fluviatile complex composed of black brownish clayey loam (*c*) with numerous Fe/Mn concretions, pale brownish gray, fluviatile, sandy loam (*d*) yellowish green clay with red mottles (*e*) breccia like clay pebble gravel (often iron stained) (*f*) and finally at the very west end, lensshaped sandfilled gullies (*g*) underlain by and intermixed with a peaty deposit (15).

Bed 13: Frost wedge row (east end), laterally going over into cryoturbatic involutions towards the west intermixed with sediments of (12).

Bed 14: Homogeneous yellowish (2.5 Y 7/6) loam.

Bed 15: Gray or black brown (10 YR 5/2) humic/peaty horizon with lumps of peat (black) and numerous Fe/Mn mottles.

Bed 16: Lacking.

Bed 17: Blueish white gley horizon in heavy clayey loam, leached.

Bed 18: Reddish soil (east end) intergrading towards bluegreen hydromorpheous soil; entirely, in heavy clayey loam; leached.

Bed 19: Blueish or brown clayey loam, unleached.

DETAIL DESCRIPTION OF THE NORTH SIDE OF THE SOGETRA SANDPIT, WEVELGEM.

Fig. 8

Bed 1: Ap horizon overlying a textural B horizon composed of a clayey sand with reddish mottles.

Bed 2: Yellowish gray loamy sand with numerous irregular pale mottles or lenses composed of loose sand; diffuse but tall frost wedges develop at this level.

Bed 3: Irregular bands of clayey gray loam alternating with sandy layers; roots (of actual vegetation?).

Bed 4: Pale olive (5 Y 6/3) loamy sand with outspoken sandy lenses; fluviatile structures at the base.

Bed 5: Idem bed 4, but slightly darker and with irregular oxydation zones.

Bed 6: Dark gray brown loam band, with cryoturbatic irregularities, locally thicker, composed of alternating loam and sand strata with fluviatile structures.

Bed 7 : Olive (5 Y 5/3) loamy sand with white sand lenses containing shell detritus sometimes, with cross bedded structure.

Bed 8: Alternating brown loam and pale sand lenses with fluvial structures and scattered little frost wedges.

Bed 9: Gray sandy loam bands with pale sand veneers; medium sized frost wedges at the base.

Bed 10: Olive (5 Y 5/3) loamy sand, rather homogeneous with sporadical very pale fluviatile sand lenses; a rather continuous loose sand layer may be followed at the base.

Bed 11: Gray (5 Y 5/1) sandy loam with thin humic bands and disturbed by numerous little frost wedges.

Bed 12: Gray olive (5 Y 5/2) light sandy loam with some more loamy and humic bands in the upper part and sandy shell-bearing lenses in the lower part.

Bed 13: Gray olive (5 Y 5/2) light sandy loam with cross bedded structure composed of alternating bands of dark loam and greenish sand; at the base exists a ravination filled with gray brown light sandy loam truncated by a continuous white sand layer. The whole is overlain by a frost wedge row.

Bed 14: Light sandy loam with fine subhorizontal stratification; sporadical white sandy lenses and small thin frost wedges.

Bed 15: Alternating brown loam and pale sand lenses with fluviatile structure and some scattered pebbles; at the top, a humic loamy sand layer with white sandy lenses and parallely inclined thin frost wedges occur.

Bed 16: Gray brown humic loamy sand with fluviatile structures overlain by a veneer of loose sand containing shell detritus; at the bottom a pebble band occurs horizontally and is composed of Paniselian sandstone fragments and eolised flint fragments; locally ravination gullies filled with green glauconiferous sand and some pebbles pearce the pebble band.

Bed 17: Gray olive (5 Y 5/2) light sandy loam with diffuse fine stratification and some veneers of loose white sand.

Bed 18: Greenish gray (5 GY 5/1) sandy loam with pale sandy and dark loamy lenses.

DETAIL DESCRIPTION OF THE GAVERS, HARELBEKE.

Fig. 9

Bed 1: Gray rusty, clayey sand overlain by the Ap horizon.

Bed 2: Brown fine sand with gray loamy lenses.

Bed 3: At the bottom of bed 3, occurs an irregular zone of greenish gray clay underlain by frost wedges.

Bed 4: Yellowish rusty sand.

Bed 5: Brown sandy loam.

Bed 6: Yellowish brown fine sand with some fluviatile structures (ripple marks).

Bed 7: Gray brown cross bedded fine sand.

Bed 8: Grayish white coarse sand with shells and sporadical frost wedges.

Bed 9: Gray brown homogeneous fine sand.

Bed 10: Yellowish gray brown quickly alternating sand and loam layers overlain by a frost wedge row.

Bed 11: Dark gray brown humic loam with sandy layers, overlain by a frost wedge row in turn overlain by an oxydized sandy layer.

Bed 12: Idem bed 10.

Bed 13: Idem bed 11 but more clayey.

Bed 14: Greenish brown loamy sand overlain by a frost wedge zone.

DETAIL DESCRIPTION OF WEST SIDE WALL, BRICKYARD « SCHABALIE », POPERINGE.

Fig. 10 and 11

Bed 1: Yellowish brown sandloam with Ap-horizon.

Bed 2: Yellowish brown sandloam with common red mottles, fine (fragipanlike) structure; overlain by a fine frost wedge row.

Bed 3: Gray brown sandloam laterally going over into cross bedded sands; overlain by a fine frost wedge row.

Bed 4: Yellowish brown thin sand and loam layer with numerous calcareous concretions and pipestems laterally going over into cross bedded sands with occasionally fine frost wedges and a pebble band at the base; the whole is overlain by rather large frost wedges.

Bed 5: Alternating fine layers of gray loam and brownish green sand with solifluidal and fluviatile, locally cross bedded structures.

Bed 6: Gray coarse, cross bedded sands with gravels with lateral transition to yellowish brown mottled loam.

Bed 7: Quickly alternating loam and sand layers, often peaty; common solifluction and cryoturbatic structures, especially in the upper part and then exceedingly strong; also frost wedges happen to occur along the upper limit.

Bed 8: Cryoturbated dark humic horizon at the base of bed 7.

Bed 9: Complex of brownish gray (peaty) loam and sand layers; with intercalations of white grayish gravelly sand bands and of brown gravelly layers composed of clay pebbles mixted with numerous Fe/Mn concretions; fluviatile, solifluction, cryoturbation and frost structures are common.

Bed 10: Black, strong humic or peaty horizon, strongly cryoturbated in places and underlain by frost wedges occasionally also a thin gravel layer.

Bed 11: Bluegray clayey or brown loam in some places separated in two parts by a sandy layer; at the base occurs a continuous gravel layer overlain locally by fine frost wedges.

Bed 12: Blue compact heavy clay.

DETAIL DESCRIPTION, BRICKYARD « DEMOULIN », SOUTH SIDE RUMBEKE.

Fig. 12

Bed 1: Ap-horizon.

Bed 2: Yellowish brown fine stratified fine sand underlain by a pebble band and very fine frost wedges.

Bed 3: Mottled yellowish somewhat clayey sand with many pebbles scattered in the bulk of it.

Bed 4: At the base of bed 3 a prominent (eolised) pebble band and a row of large frost wedges and cryoturbation pockets.

Bed 5: Yellowish brown loam with gray mottles and red ferruginous « pipestems », the whole is affected by bound cryoturbatic undulations fading out towards the bottom.

Bed 6: Gray fine layered loam with in places, a row of fine frost wedges and a thin pebble band at its base; in the latter case, discordance with underlying bed 7 well expressed.

Bed 7: Pale gray loam, somewhile containing mollusk shells; two dark gray humic bands, most often slightly disturbed by cryoturbation, can be distinguished; fluviatile structures are observed towards the east end of the section with clay and flint pebbles at the base of it.

Bed 8: *a*) Pale green brown fluvial loam, locally affected by bound cryoturbations and then of a more sandy texture; contains clay pebbles and peaty lumps;
b) Greenish gray fluvial loam with humic lenses; reddish solifluction structures at the top and somewhat gravelly at the base.

Bed 9: Four series of cross bedded sands, pebble band, frost wedge row, fluvial gray loam and peaty loam, sometimes loamy peat at the very west end of the section. Towards the east, these deposits laterally go over into a uniform thick bed of fine layered pale green loam and sandloam and ultimately end up with a fluvial and/or solifluction complex of sands, loams and peaty layers.

Bed 10: A series of alternating sand and loam layers, somewhat peaty or with peaty layers in between; locally only a prominent peat layer is present. The whole shows definite fluvial structures as well as cryoturbatic disturbances. The bottom layers are often characterized by the presence of numerous Fe/Mn concretions and clay pebbles.

Bed 11: Gray loam with yellowish coarse sandy bands underlain by either a veneer of peaty lenses or a well developed peat horizon.

Bed 12: Gray blue clay or silty loam locally with humic lenses.

Bed 13: A series of fluvial loamy peat layers, occasionally with pebbles; rather continuous extension.

Bed 14: Gray blue sandy and clayey loam with scattered humic lenses separated by a fine frost wedge row from underlying brown fine sandy loam and even fine sands with gravel lenses.

Bed 15: Blue compact, schistoid clay.

DETAIL DESCRIPTION OF NATURAL SINKHOLE (ESQUELMES).

Fig. 13

Bed 1: Surface soil with Ap-horizon.

Bed 2: Clayey sand mixed with greenish loose sand.

Bed 3: Textural-B-horizon.

Bed 4: Brown loamy sand, leached.

Bed 5: Brown gray loamy sand and loam with sandy solifluction lenses, cryoturbated at the base and with fine diffuse frost wedges along the upper limit; leached.

Bed 6: Alternating brown calcareous loam, with plant remains, and pale fine sand; irregular stratification; numerous Ca-concretions.

Bed 7: Yellowish green fine sand.

Bed 8: Gray brown loam layer underlain by a fine sand layer from which it is separated by a cryoturbatic contact line. At the base of the sand layer a pebble band may be present.

Bed 9: Alternating yellowish loamy sand and gray brown loam with Ca-concretions; fluvial structure; from the upper limit, fine frost wedges extend downwards.

Bed 10: Gray brown sandy loam.

DETAIL DESCRIPTION OF NATURAL SINKHOLE AT HERINNES.

Fig. 14

Bed 1: Ap-horizon underneath a thin layer of overburden.

Bed 2: White (leached) sand.

Bed 3: Brown clayey sand, with common gley mottles (« marmoriert ») and numerous Fe /Mn concretions at its base.

Bed 4: Grayish white clay band.

Bed 5: Brown fine sand, gleyified with brown clayey band at the base.

Bed 6: Gray brown loamy sand with irregular stratification.

Bed 7: Brown clayey loam with vegetation remnants underlain by a fragipanlike horizon.

Bed 8: Yellowish sand with irregular gray brown loam bands.

Bed 9: Brown clayey loam with vegetation remnants and gley.

Bed 10: Gray brown clayey loam overlain by cryoturbated thin sand layer.

Bed 11: Yellowish loamy sand with gley mottles overlain by frost wedge row in turn overlain by a pebble band.

DETAIL DESCRIPTION OF TUNNELPIT, ZELZATE.

Fig. 15, 16, 17, 18

Bed 1: Man made soil dark grayish (O.G. of section 1).

Bed 2: Dark brown humic sand with plant remains and irregular brown bandering at the base (Podzol-B-horizon) (B. HUM of section 1).

Bed 3: Brownish yellow sand with fine texture, homogeneous; with rootlets and some horizontal stratification at the base (B.Y. SAND of section 1).

Bed 4: Dense zone of plant remains (rootlets) in white grayish sand (W.G. SAND of section 1); dark brown humic layer at the top overlain by fine frost wedgelike structures.

Bed 5: Whitish fine sand (W.F. SAND in section 1) with irregular stratification; alternation of pure sandy and more loamy layers; vegetation dots and Fe/Mn spots; locally at the base prominent cross bedding of subhorizontal thin layers (2 to 3 cm in thickness) (Section 5).

Bed 6: Peaty layers with horizontally interbedded sand. Locally they occur very closely together, elsewhere they form separate peaty bands. The upper limit is rather irregular and apophyses pearce into the sands of bed 5 (L. Peat of section 1).

Bed 7: Yellow brown loamy sand (L. SAND of section 1) with many horizontally interbedded more loamy beds; towards the base, gray clay bands occur with oxydation zone underneath; the bands are discontinuous, cryoturbatic with the clay sometimes smeared out between the sandy layers. In the oxydation zones white patches and calcic spots are present; featherlike stratification (detail section 5).

Bed 8: Complex of several sand layers: gray brown sand horizontally stratified with loamy bands (G.B. SAND of section 1), brown humic sand rather homogenous (H.B. SAND of section 1) and gray sand with fine peaty bands (P. SAND of section 1).

Bed 9: Contact line sharply materialized by a pebble pavement on top of bundles of heavy clay layers (with dropping structures) (section 5), or cutting through them (section 1), faintly observable fine frost wedges are seen below (almost 1 m in length).

Bed 10: Complex of sand: fine loamy sand (F.L. SAND section 1), whitish gray sand (W.G. SAND of section 1), dark brown sand (B.D. SAND of section 1), sandloam (SANDLOAM) with clayey lenses and shell detritus, yellowish gray cross-bedded sand (Y.G. SAND of section 1), white loamy sands (W. SAND of section 1) with clay breccia (section 5), brownish yellow sand with darker bands (B.Y. SAND of section 1) and coarse cross-bedded sands (foreset beds) with shell detritus (C. SAND of section 2), brown clay bands and vegetation remnants (section 5).

Bed 11: Brown gray sandy and loamy layers with irregular undulations, the base of which pearces in the underlying layer; shell detritus (F. SAND of section 2).

Bed 12: Cryoturbatic layer built up by reddish brown loam with vegetation remnants; disturbed peaty horizon; gray loam with pale sandy layers showing very irregular involutions (C. LOAM of section 2).

Bed 13: Greenish gray loam with pale whitish disturbed sandy layers (cryoturbatic); shells sporadically; at the top, dark gray brown heavy loam somewhat humic (soil horizon) (C. LOAM of section 2).

Bed 14: Dark, greenish gray, clayey loam with many shells (D.G. LOAM).

Bed 15: White and red irregular, quickly alternating bands of sand and loam (S & L of section 2); more white sandy (section 5); locally large frost wedge starting from top (section 3).

Bed 16: Green gray sandy loam or clayey loam (S. LOAM of section 2); horizontally stratified; locally congelifracted flint gravel; on top, gray brown homogeneous loamy clay (soil horizon) with many shells; more peaty locally (section 5).

Bed 17: Dark gray brown clayey loam with blue heavy clay lenses; calcic concretions and landmollusks (*Pupa muscorum*, *Succinea*, etc.) (section 2). Elsewhere this layer becomes completely sandy with shells (section 4). Base and top locally somewhat cryoturbatic (section 5).

Bed 18: Brown gray, very clayey loam with thin pale sand lenses; at the base, blue reduction zone (section 2, B.C. LOAM).

Bed 19: Complex of pale brown clayey loam and red brown clay (soil) (R. CLAY of section 2) resting on green gray loamy sand glauconiferous and with a great amount of shell detritus (L. SAND of section 2).

Bed 20: Ravinations filled up with coarse sand and gravel, peaty lenses, shell detritus (section 4).

Bed 21: Alternation of gray fine sand and brown gray clay layers: many reworked Tertiary shell detritus; in the middle zone with clay pebbles and clay breccia; sporadically flint (section 4).

Bed 22: Very coarse gravel with big blocks of fresh flint (20 cm diameter), clay pebbles and fossils (*Corbicula fluminalis; Tapes senescens var. eemiensis, Cardium edule*) (section 4); humic horizon on top and shallow ravinations filled with detritus peat.

DETAIL DESCRIPTION OF SIFFER DOCK PROFILE (GHENT).

Fig. 19

Bed 1: Dark grayish (10 YR 4/2) brown, leached humic loamy sand with white tubules and Fe-concretions (Ap-horizon).

Bed 2: Yellowish leached medium fine sand, with Fe-concretions in the upper part (Bir) and common reddish clayey mottles in the lower part (B_2t); many Fe/Mn concretions.

Bed 3: White gray heavy clay.

Bed 4: Yellowish medium fine cross bedded sand ravinating underlying deposits.

Bed 5: Gray loamy sand alternating with more loamy discontinuous layers; fine deepgoing frost wedges develop in it, starting at the upper limit.

Bed 6: Sequence of quickly alternating pale sandy and dark gray loamy layers with outspoken fluviatile structure and numerous little frost wedges inclined in the same direction.

Bed 7: « Dropping structures » (« druipstaart ») composed of very plastic clay interfering with very fine frost wedges (10 cm deep; 1 cm thick); lower limit of leached beds.

Bed 8: Brown cross bedded, loamy sand.

Bed 9: Stone line composed of little eolised flint fragments.

Bed 10: Sequence of quickly alternating pale sandy and dark gray loamy layers, some of them being entirely oxydized; the sand layers are shell-bearing and with outspoken fluviatile structure.

Bed 11: White gray sand with shells.

Bed 12: Yellowish brown homogeneous loamy sand.

Bed 13: Semi-coarse white sand veneer.

Bed 14: Dark gray brown homogeneous sandy loam with many plant spots; irregular lower junction line (solifluction).

Bed 15: Yellowish brown or reddish brown, cross bedded coarse sands, alternating locally with loamy lenses (40 cm in thickness); distinct ripple mark structure; in places layers with inclination in the same direction (beach deposits); sporadically small gullies composed of very coarse sand and even gravel (flint pebbles up to 2 cm diameter); occasionally with peaty layers and usually, numerous Tertiary reworked shells (*Numilites planulatus, Cardita planicostata*, etc.); fine gray clay pebbles; also fine (2 to 3 cm in width), deepgoing (1 to 2 m long) frost wedges may occur, pearcing throughout the cross bedding, and usually starting at the basis of loamy intercalations.

Bed 16: Yellowish brown semi-fine layered sand, filling up broad shallow depressions; they may attain 100 m in length and be only a few metres in depth; sharp, discordant lower limit.

Bed 17: Green fine, loamy sand, with featherlike cross bedded structure; the «feathers» are dark coloured due to a high content of humic components; shell detritus may occur locally; the lower limit is built up by a white gray coarse sandy layer thus establishing a sharp discordance line.

Bed 18: A series of recurrences of the following succession (from top towards bottom): pale sand quickly alternating with dark brown loam bands; numerous rust mottles, shell detritus and plant remains (bottom part); follows below, a white gray glauconiferous sand with shells (*Bythinia; Pupa muscorum; Succinea* and also reworked *N. planulatus*) and shell-detritus at the bottom of which fine irregular frost wedges start to develop; next comes the main body composed of gray brown featherlike cross bedded sand and (darker) loam layers the latter being often peaty at the base; the layering becomes more compact with depth.

Bed 19: Dark gray brown alternating sand and loam showing a typical foreset bed structure (layers 2 mm thick); the lower boundary is indicated by a blue gray loamy sand layer with elongated peaty threads.

Bed 20: Greenish gray fine sands with fine foreset bed structure; loamy lenses and shell-bearing.

Bed 21: Several layers of gravels mainly composed of rolled flint, sandstone, quartzite pebbles and numerous little, flat clay pebbles and also peat lumps; *C. fluminalis* and sporadically *T. senescens*, occur within the rich mollusk fauna of these gravels.

Bed 22: Greenish gray fine cross bedded sand with peaty threads (and then with featherlike structure) and gullies filled mainly with shells and a great abundance of clay pebbles; locally thick loamy bands may be intercalated and also tree stumps (*Picea*) may occur in it.

Bed 23: Coarse gravel composed of big rolled flint pebbles and large rolled, dark green, Paniselian sandstone fragments (20 cm).

Bed 24: Peaty clay.

Bed 25: Pale grayish green sand alternating with violet loamy clay layers, irregularly layered; micro-pseudo-tectonic faults usually occur; at the top of it, a peaty horizon has developed in a clayey matrix but different from bed 24, and is furthermore characterized by its strongly cryoturbaticlike disturbed nature (25').

DETAIL DESCRIPTION OF S.V.K. BRICKYARD, SINT-NIKLAAS.

Fig. 20

Bed 1: Reworked ground.

Bed 2: Yellowish sand carrying a Bir-horizon at the top; rust spots at the base.

Bed 3: Large frost wedge (upper limit).

Bed 4: Gray loam with rust spots at the base.

Bed 5: Grayish sand, fine layered, with rust spots.

Bed 6: Gray loam with lensshaped sand lenses (ripple marks?).

Bed 7: Grayish sand.

Bed 8: Gray sandloam.

Bed 9: Gray homogeneous loam.

Bed 10: Gray loam with sand layers laterally going over into cross bedded sands filling up ravinations.

Bed 11: Gray loam with sand lenses, becoming more sandy towards the bottom and locally with breccia-like structure (br.).

Bed 12: Gray loam with thick sand lenses (gravelly) and rustspots.

Bed 13: Sands and gravels with numerous shark teeth, rolled shells, bones, flint and quartz pebbles.

Bed 14: Clay (of Boom).

DETAIL DESCRIPTION OF SCHONENBERG, MECHELEN.

Fig. 21

Bed 1: Ap-horizon.

Bed 2: Brown homogeneous sand within which textural B horizon has developed; in the upper zone Fe-concretions.

Bed 2': Large frost wedge row with cryoturbation pockets.

Bed 3: Alternating fine layers of sand and loam with dispersed fine frost wedges.

Bed 4: Stone line underlain by a discontinuous frost wedge row.

Bed 5: Light brown sandloam with ripple marks fainting out towards the south end of the section and becoming outspoken sandy.

Bed 6: Idem as bed 5 and overlain by a fine sandy veneer, occasionally shallow gullies filled with coarse yellowish sand, the upper limit coinciding with sporadically displayed fine frost wedges and cryoturbatic involutions.

Bed 7: Pale grayish, medium fine sand with distinct fluviatile structures (cross bedding), the upper limit coinciding with sporadically displayed fine frost wedges and cryoturbatic structures.

Bed 8: Idem as bed 5 and 6, but for the presence of numerous little frost wedges and the lack of frost features along the upper boundary.

Bed 9: Discontinuous pebble band underlain by discontinuous row of small frost wedges.

Bed 10: Series of three fine sand layers with occasionally frost wedges at their base and separated by two thick layers of compact leavelike structured blue gray loam.

Bed 11: Complex of irregularly alternating sand and loam layers.

DETAIL DESCRIPTION OF SANDPIT LACHENENBEEK, HINGENE.

Fig. 22

Bed 1: Peat often mixed with mineral components.

Bed 2: Yellowish brown sand, fine layered.

Bed 3: Quickly alternating gray peaty loamy layers and brown gray sandy layers, often highly cryoturbated, occasionally frost wedges.

Bed 4: Gray sandloam with fluviatile structures and locally gullies; the lower limit may show frost wedge-like and cryoturbation structures.

Bed 5: Cross bedded sands, with occasionally foreset structures and loamy lensshaped intercallations; fine deepgoing, featherlike frost wedges may occur.

Bed 6: Cross bedded loamy sands, with numerous peaty layers.

Bed 7: Gray loam and coarse sands containing peat lenses composed of fine plant twigs.

Bed 8: Fine gravel in coarse gray sand matrix.

DETAIL DESCRIPTION OF DRY-DOCK SECTIONS (E3-TUNNELWORKS), ANTWERP, WEST BANK.

Fig. 23, 24 and 26

Bed 1: Peat.

Bed 2: Blue gray coherent sand when wet, and yellowish sand when dry, locally clayey, impregnated with roots from overlying peat; hydromorphic soil or podzol on top; occasionally white calcic spots and dark humic mottles.

Bed 3: Humic gray loam layer with plant remains or hydromorphic soil; in places overlain by pebble layer composed of gray sand stones, eolised flints and sporadically iron concretions; locally replaced by a grayish coarse sandlayer.

Bed 4: Blue grayish coarse sands.

Bed 5: Peat horizon with many mollusks thinning out towards the Scheldt where it first splits into three peaty layers separated by sandy layers and finally going over into a system of alternating sand and loam layers with locally sandstones in the top layers and clay breccia in the bottom layers.

Bed 6: Grayish medium coarse sand.

Bed 7: White grayish loam with many rootlets and mollusks becoming very humic before disappearing completely in the sand and loam system of bed 5 towards the Scheldt.

Bed 8: Basal gravel with vertebrate bones, shell layers (*Pisidium*, etc.), flint pebbles and fresh blocks of septaria; also artifacts e.g. levalloisian point and flakes. Widens out into a system of coarse, white grayish cross bedded sands.

Bed 9: White grayish gravelly sand, irregularly stratified with lenses of Boom clay and sporadically reworked Tertiary shells as well as vertebrate bones; ravinations with detritus peat.

Bed 10: Brown reddish coarse sand with worn flint and calcite concretions; brown horizon remembers B_{ir}-horizon of podzolic soil.

Bed 11: Gray loamy layer with plant remains locally disturbed by ravinations, the whole being truncated by the red brown coarse sand of bed 10.

Bed 12: Greenish sand with a gravelly layer at the base.

Bed 13: Sands of Edegem (Tertiary).

Bed 14: Clay of Boom (Tertiary).

DETAIL DESCRIPTION OF TRAINTUNNEL SECTIONS, ANTWERP, EAST BANK.

Fig. 28 and 29

Bed 1: Peat.

Bed 2: Yellowish sand with podzol in upper part.

Bed 3: Pebble band underlain by frost wedges or cryoturbatic involutions.

Bed 4: Complex of pale gray homogeneous eolian sand and zones of quickly alternating sand and loam layers, disturbed by solifluction and cryoturbation structures as well as frost wedges; in the top zone, a dark green blueish sand, somewhat clayey and with plant remains, is usually present and is often strongly cryoturbated; in places, a similar humic horizon, with crotovines is found at the bottom; sometimes overlain by a continuous row of frost wedges; a radiocarbon dating was taken at this level.

Bed 8: Pebble band in places becoming a gravel bed with shells filling up shallow gullies: at the bottom, frost wedges may be found.

Bed 9: Peat gullies.

Bed 10: Yellowish red (5 YR 4/8 à 4/6) horizon.

Bed 11: Greenish brown fluvial sand, with sporadical shells laterally going over into pale green fine sands with ripple mark structure and subhorizontal thin gravel layers.

Bed 12: Cross bedded gravel deposit with great abundance of shells and vertebra remnants.

Bed 13: Greenish fine sands of Edegem (Tertiary).

Bed 14: Boom clay.

DETAIL DESCRIPTION OF ENTRANCE OF E3-TUNNEL, NORTH WALL, ANTWERP, WEST BANK.

Fig. 25

Bed 1: Peat.

Bed 2: Blue gray loamy sand.

Bed 3: Gray coarse sand.

Bed 4: Alternating fine layers of sandloam and sand.

Bed 5: Dark gray sandloam with fine vegetation remnants.

Bed 6: Dark gray diffuse bedded sands with foreset structure at the base.

Bed 7: Alternating fine layers of gray sand and loam.

Bed 8*a*: Yellowish coarse sand with scattered iron patches.

Bed 8*b*: Yellowish coarse sand mixed, locally, with Fe/Mn bands, and rolled peat lumps.

Bed 8*c*: Grayish white, medium coarse sand, leached, mixted with irregular lumps of yellowish red (5 YR 4/8) ferruginous zones which may follow the stratification or extent downwards in bed 10.

Bed 9: Gullies filled with detritus peat.

Bed 10: Dark brown (7.5 YR 4 /4) fine cross bedded sand the topzone of which may be leached or contain ferruginous zones extending from bed 8*c*. The upper boundary is irregular due to the ravinating character of the overlying gravels; along this contact fine frost wedges may appear.

Bed 11: Complex of fluviatile gray fine sand and loam with numerous fine peaty layers; locally a peat gully; the whole shows a cross bedded structure.

Bed 14: Compact blue Boom clay (Tertiary).

Photo 5
WARNETON

Photo 6 WARNETON

Photo 7
WARNETON

Photo 8 POPERINGE

PLATE 2

Photo 9 ZELZATE

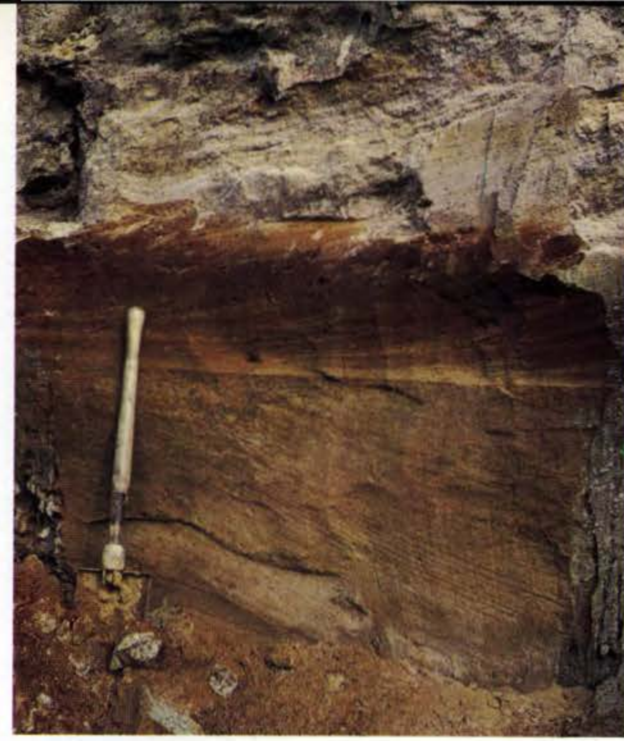


Photo 10
ANTWERP
(Left Bank)

Photo 11 ZELZATE

Photo 12
ANTWERP
(Right Bank)

PLATE 3

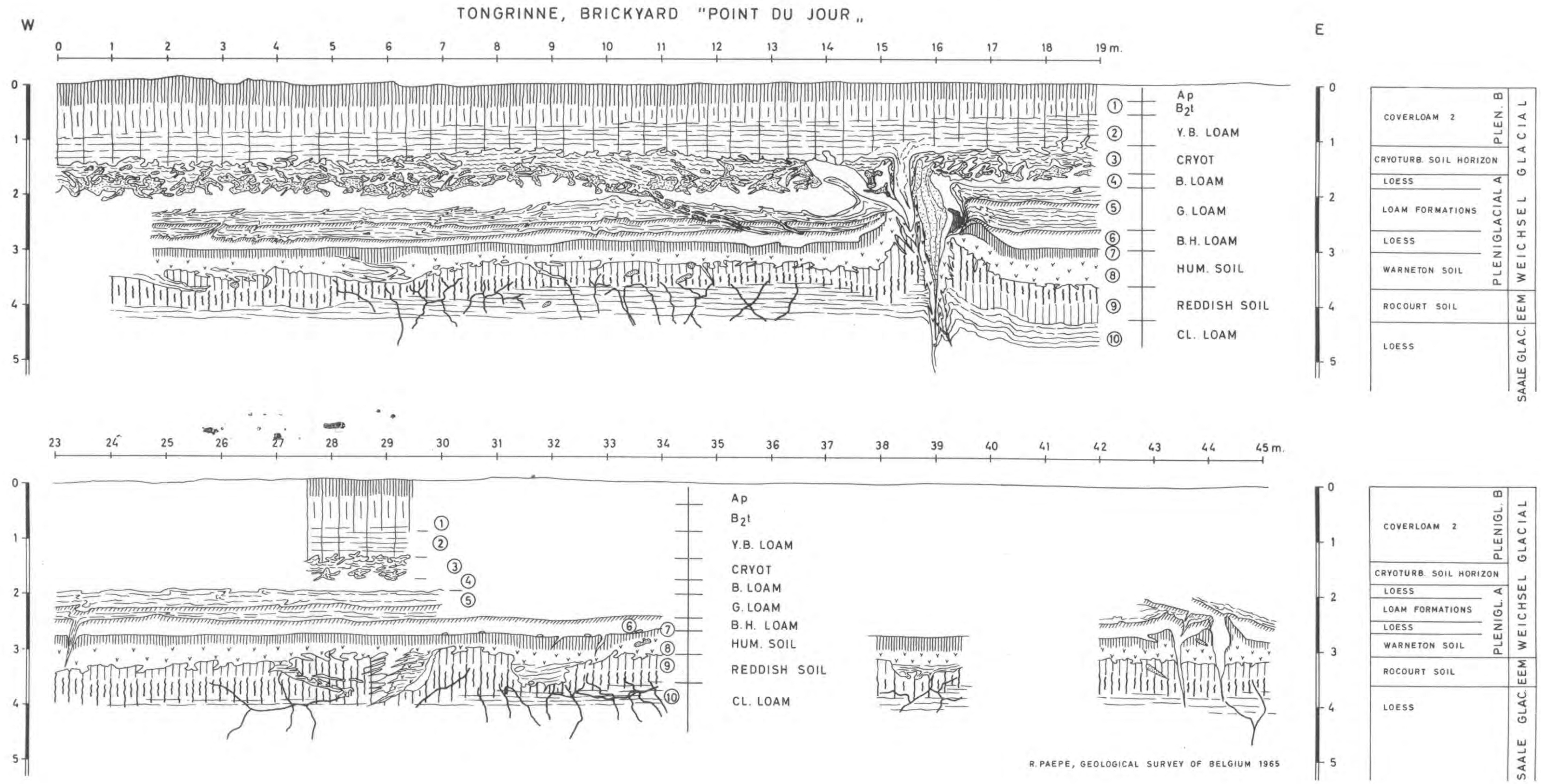
Photo 1
TONGRINNE

Photo 2
WARNETON

Photo 3
TONGRINNE

Photo 4
WARNETON

PLATE 1


TONGRINNE, BRICKYARD "POINT DU JOUR„
W
E
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Y.B. LOAM
CRYOT
B. LOAM
G. LOAM
B.H. LOAM
HUM. SOIL
REDDISH SOIL
CL. LOAM
COVERLOAM 2
CRYOTURB. SOIL HORIZON
LOESS
LOAM FORMATIONS
LOESS
WARNETON SOIL
ROCOURT SOIL
LOESS
PLEN. B
PLENIGLACIAL A
WEICHSEL GLACIAL
EEM
SAALE GLAC.
PLENIGL. B
PLENIGL. A
R. PAEPE, GEOLOGICAL SURVEY OF BELGIUM 1965

FIG. 2

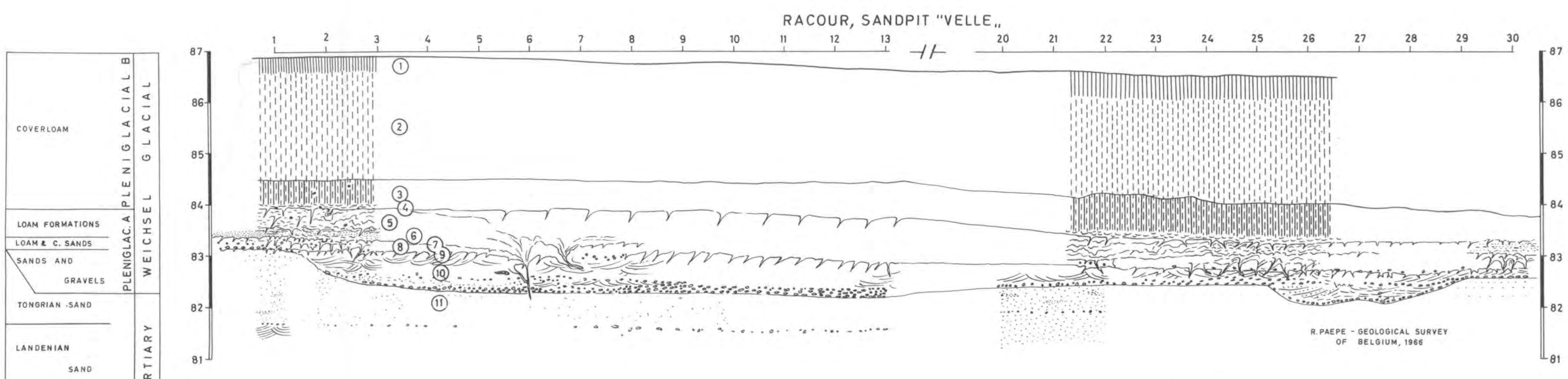
RACOUR, SANDPIT "VELLE„
COVERLOAM
LOAM FORMATIONS
LOAM & C. SANDS
SANDS AND GRAVELS
TONGRIAN SAND
LANDENIAN SAND
PLENIGLACIAL B
PLENIGLAC. A
WEICHSEL GLACIAL
TERTIARY
R. PAEPE - GEOLOGICAL SURVEY OF BELGIUM, 1966

FIG. 3

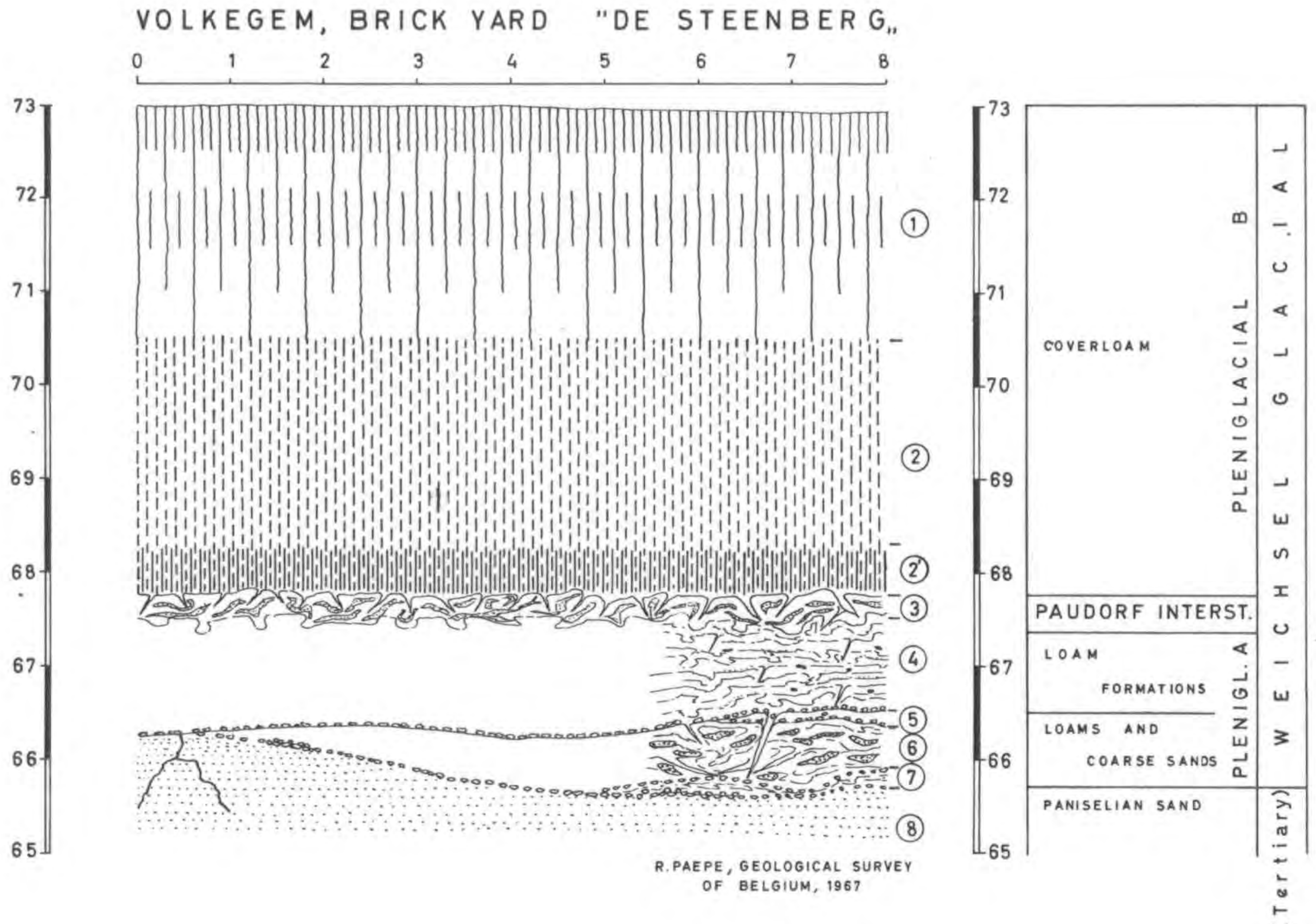

FIG. 4

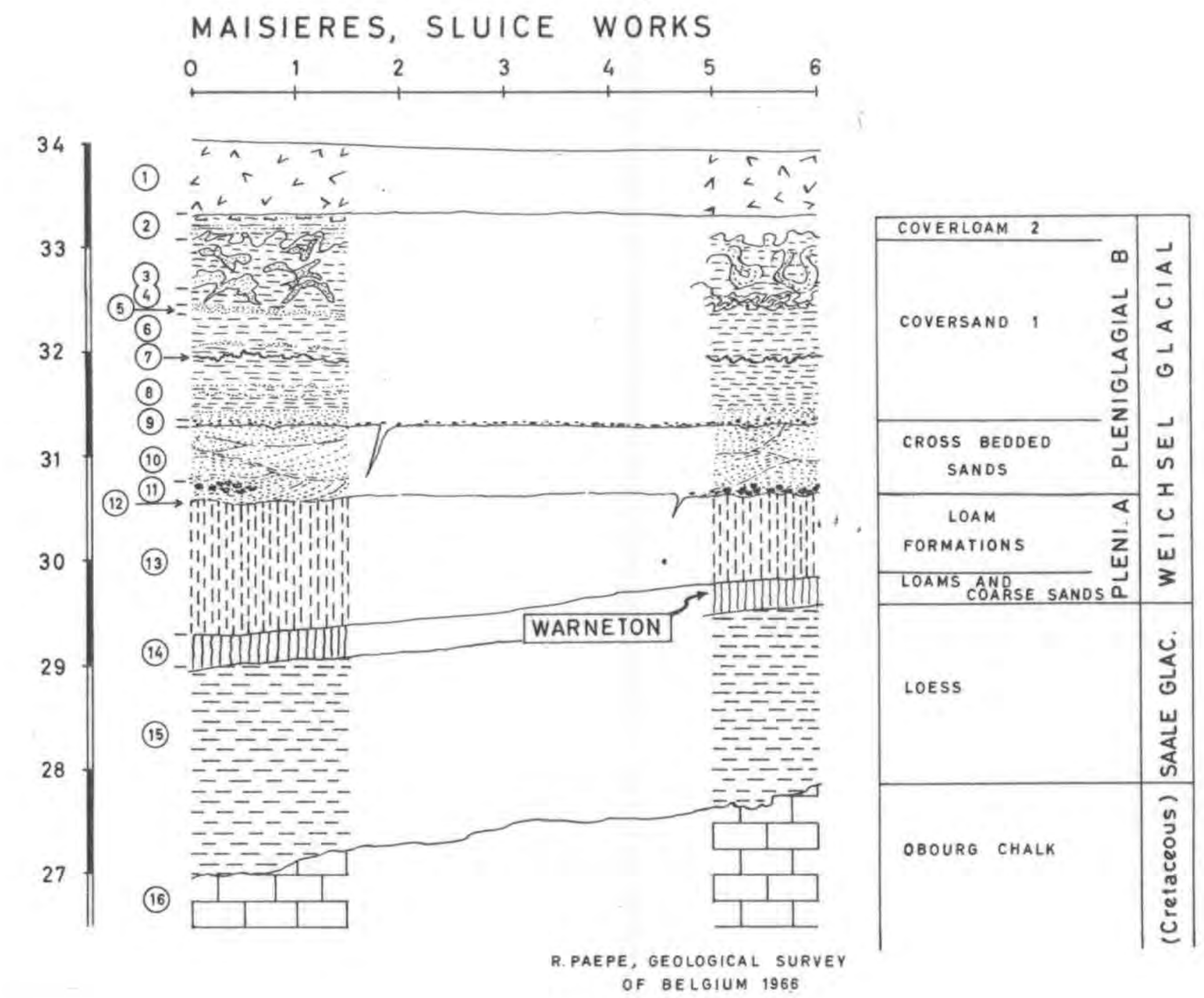

FIG. 5

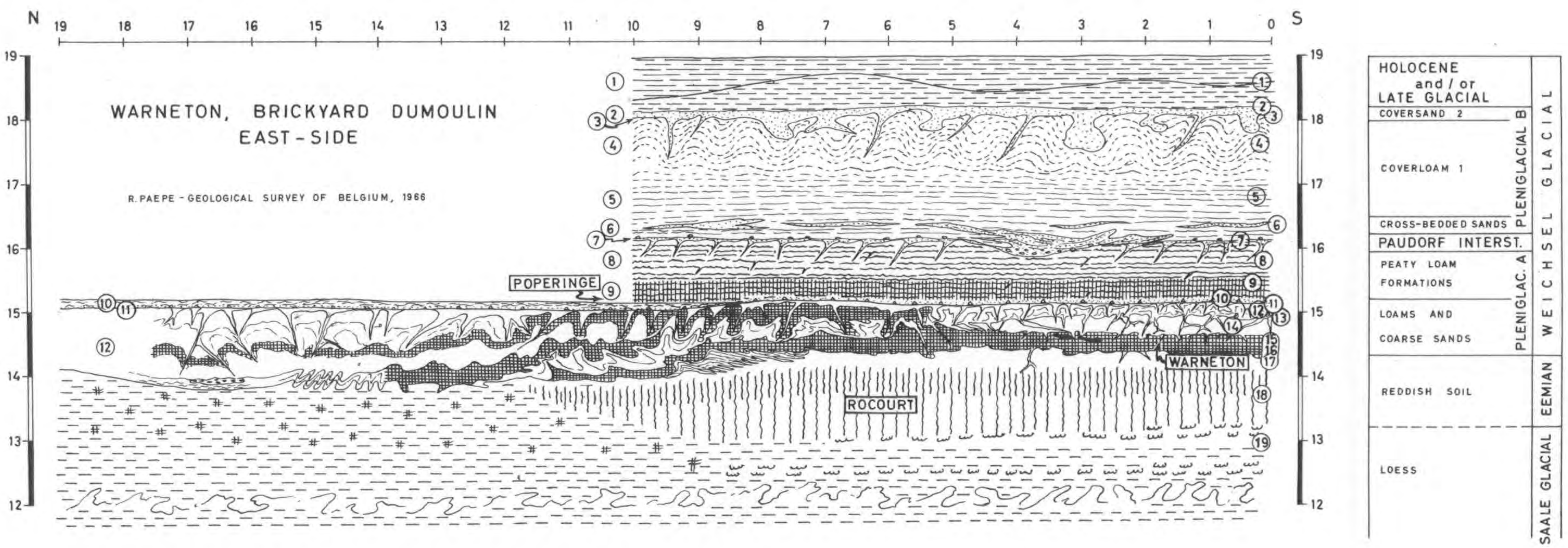

FIG. 6

FIGURES 4-5-6

FIG. 7

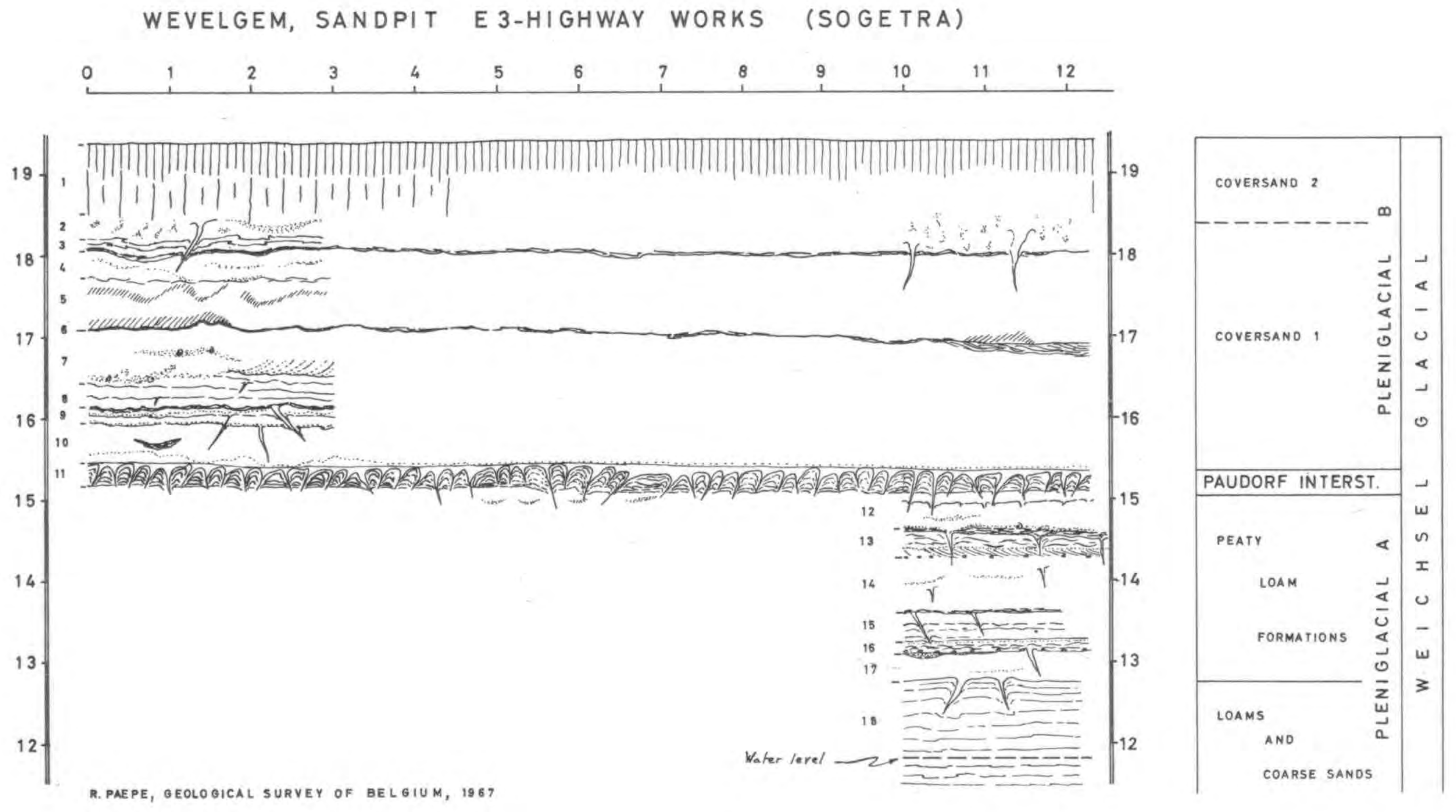

FIG. 8

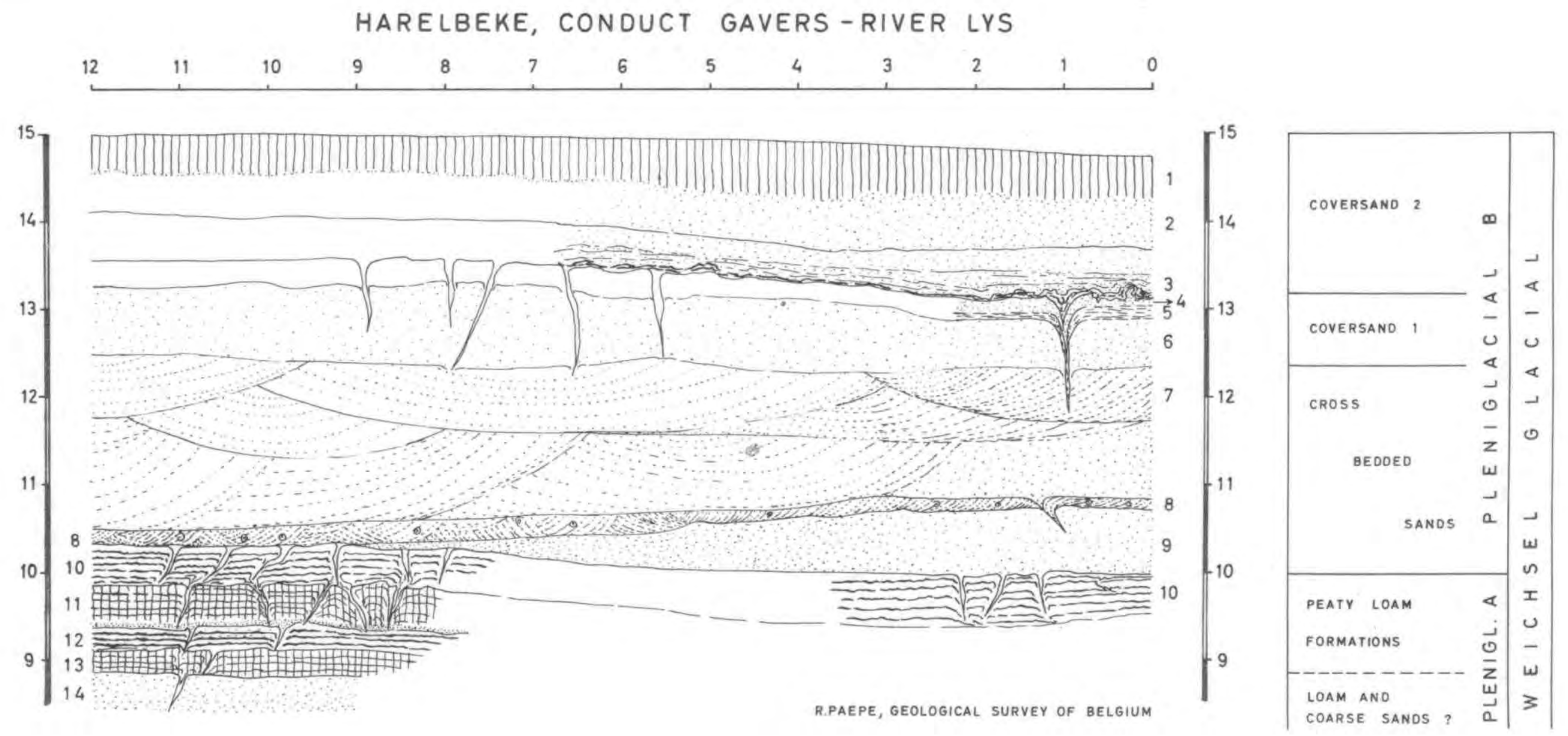

FIG. 9

FIGURES 7-8-9

FIG. 10

FIG. 11

FIGURES 10-11

FIG. 12

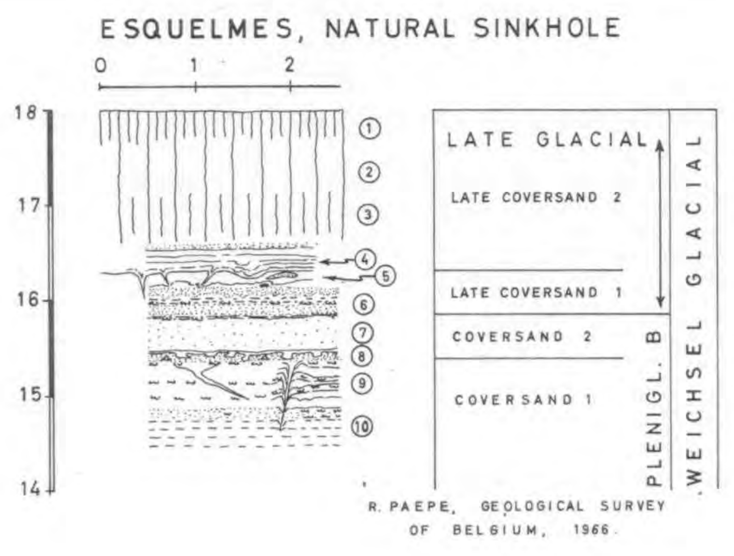

FIG. 13

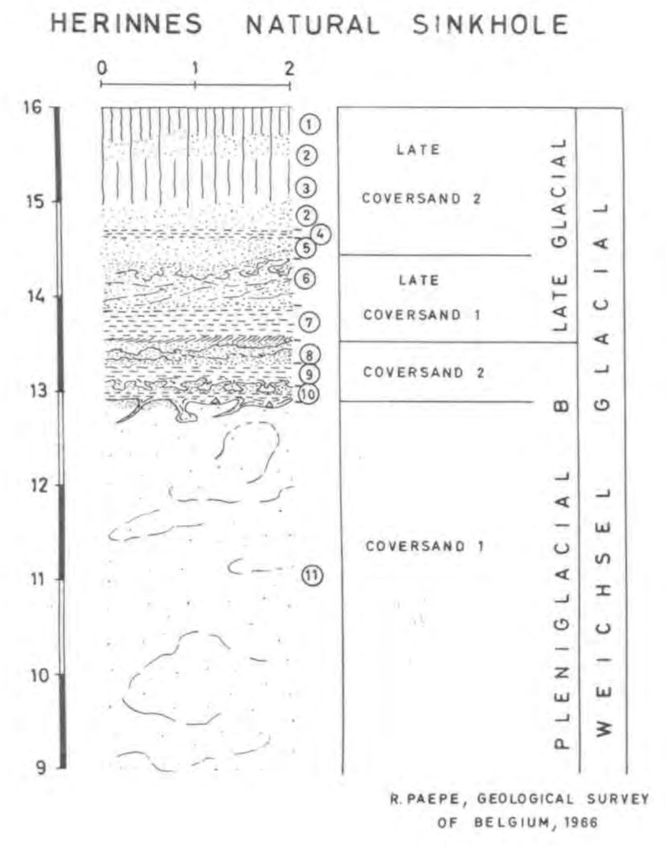

FIG. 14

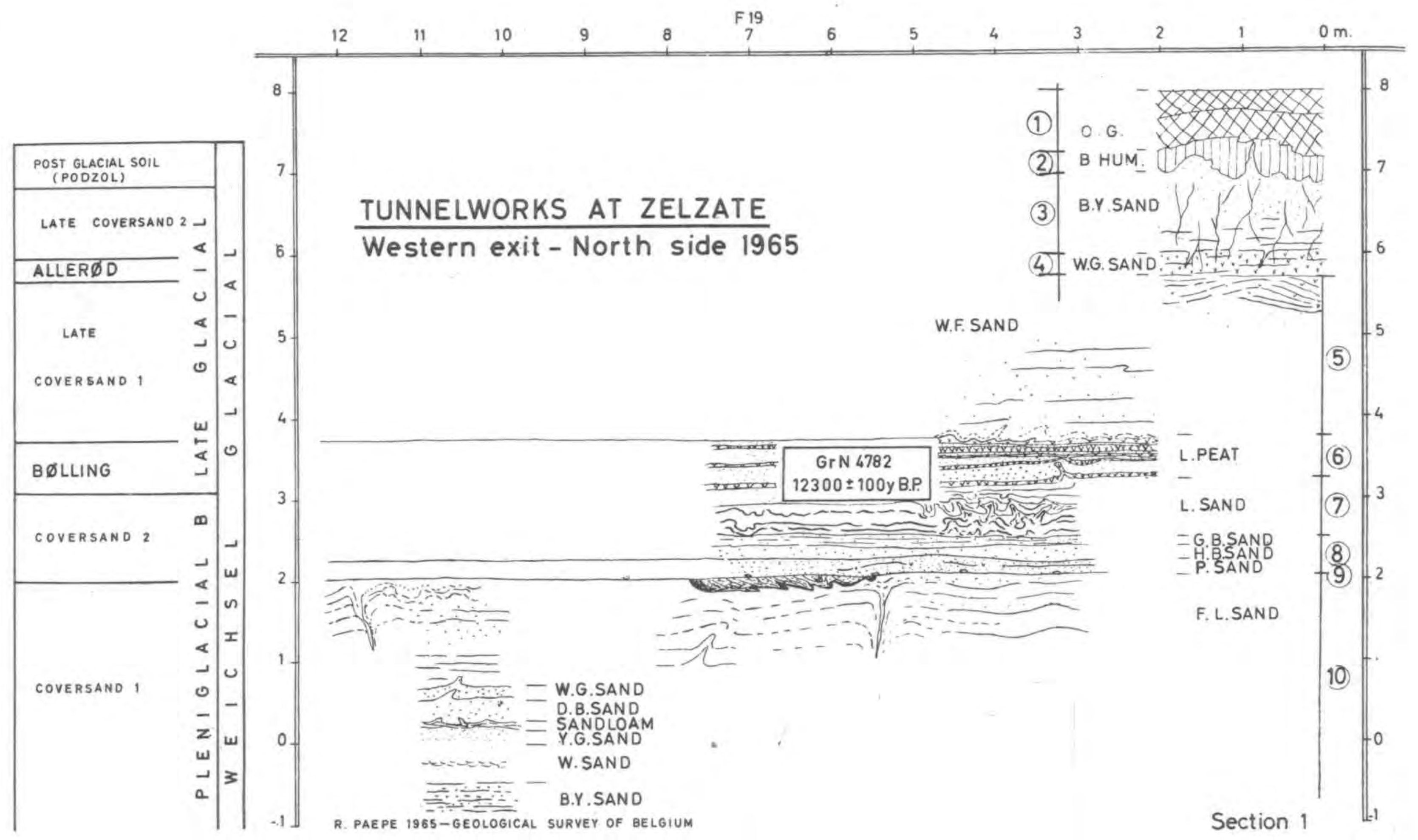

FIG. 15

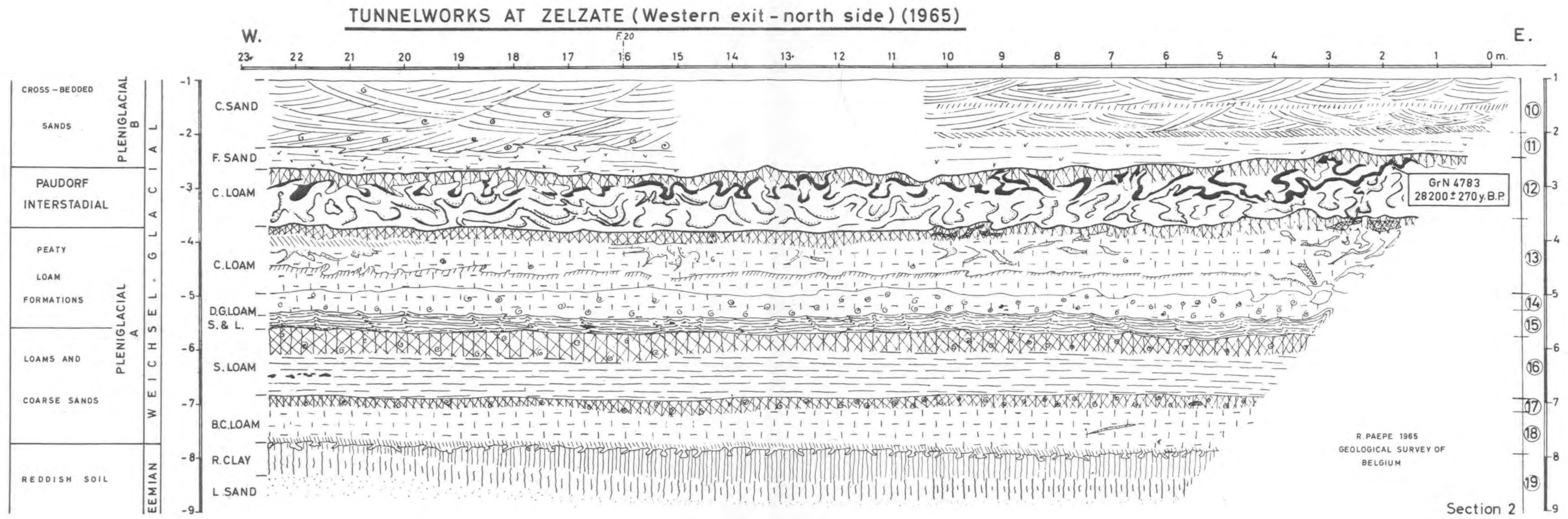

FIG. 16

FIGURES 12-13-14-15-16

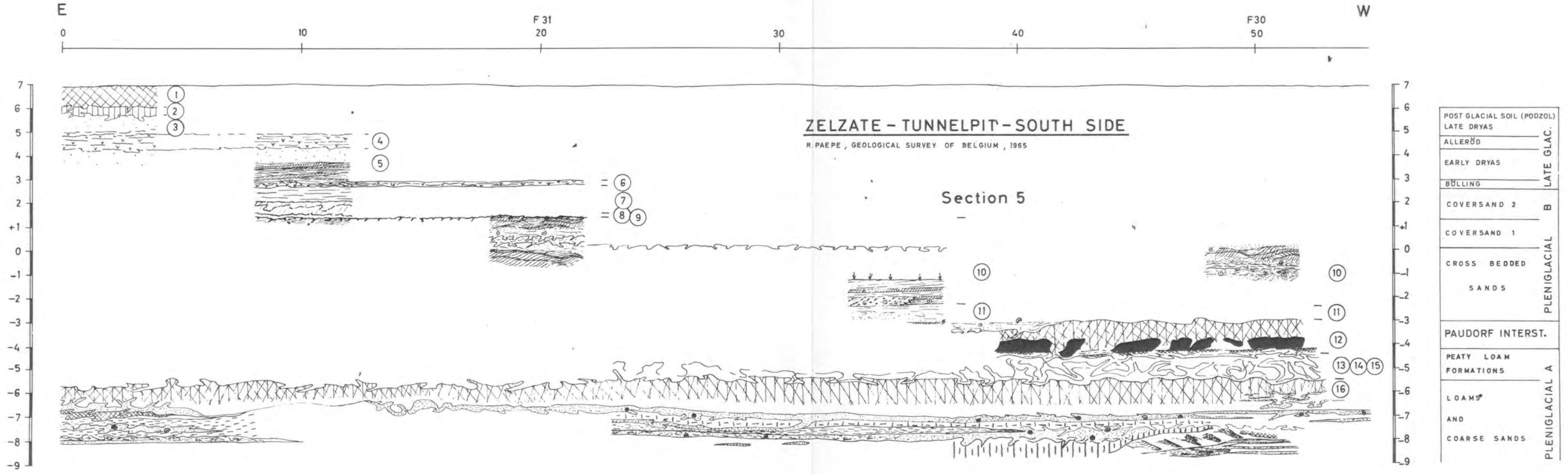

FIG. 17

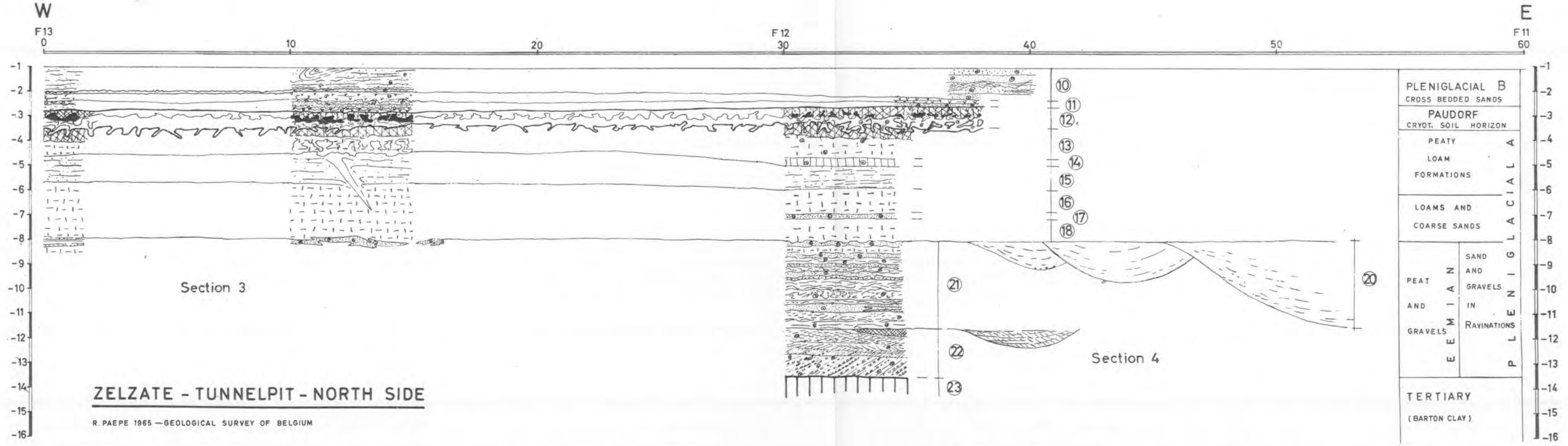

FIG. 18

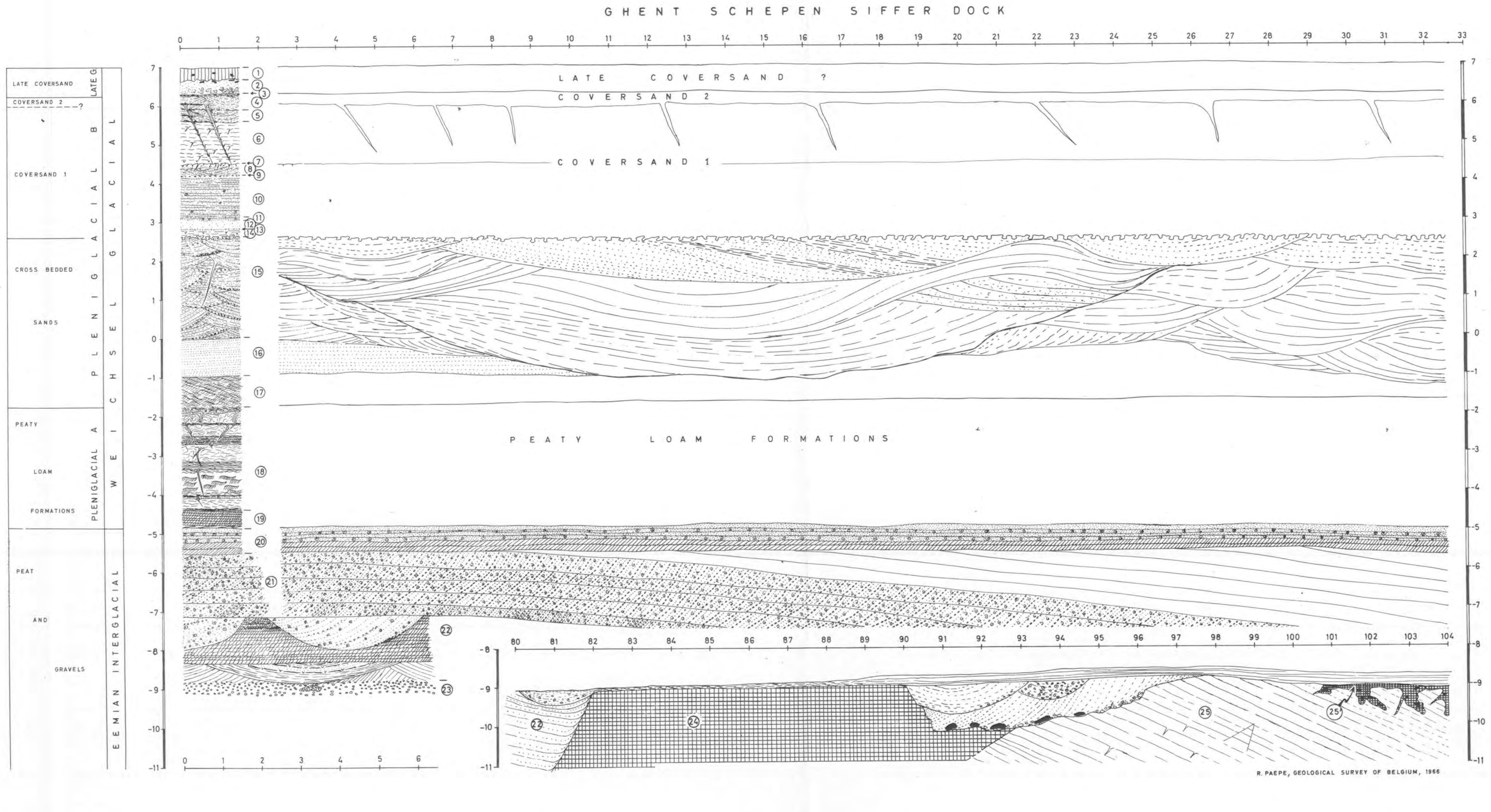

FIG. 19

FIGURES 17-18-19

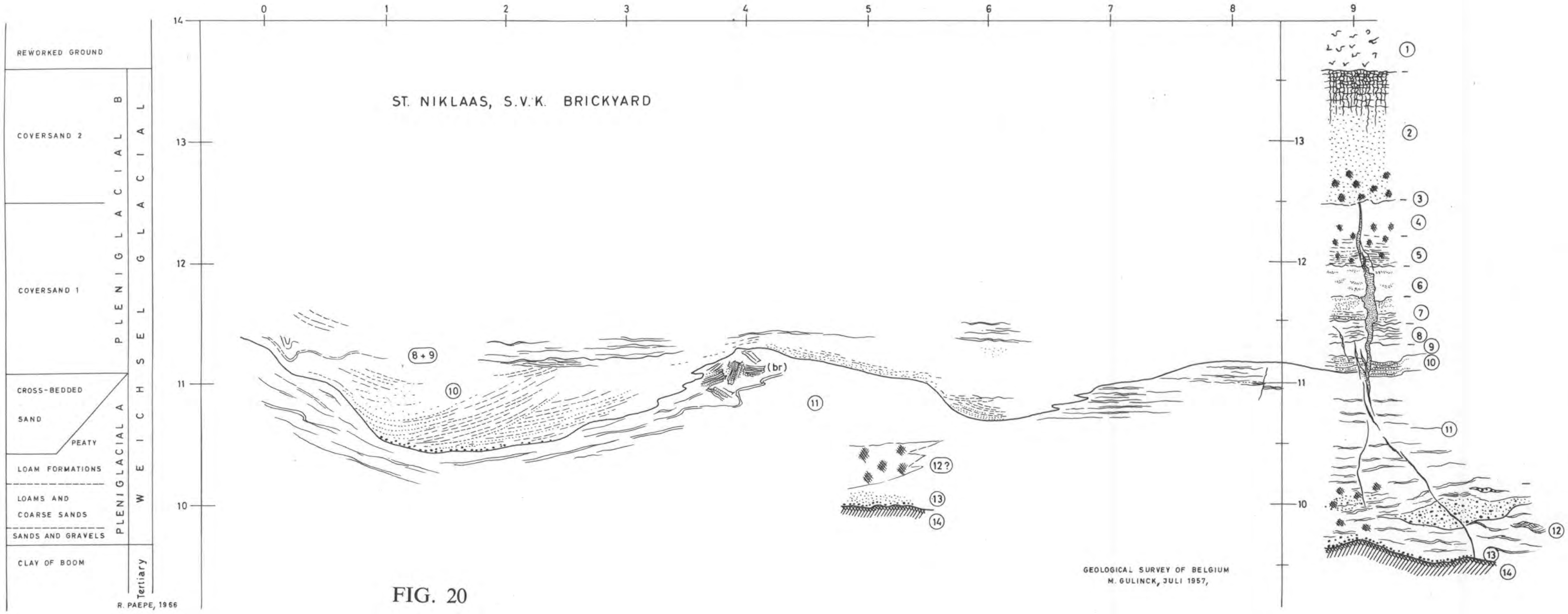
ST. NIKLAAS, S.V.K. BRICKYARD
REWORKED GROUND
COVERSAND 2
COVERSAND 1
CROSS-BEDDED
SAND
PEATY
LOAM FORMATIONS
LOAMS AND
COARSE SANDS
SANDS AND GRAVELS
CLAY OF BOOM
PLENIGLACIAL B
PLENIGLACIAL A
WEICHSEL GLACIAL
Tertiary
R. PAEPE, 1966
GEOLOGICAL SURVEY OF BELGIUM
M. GULINCK, JULI 1957,

FIG. 20

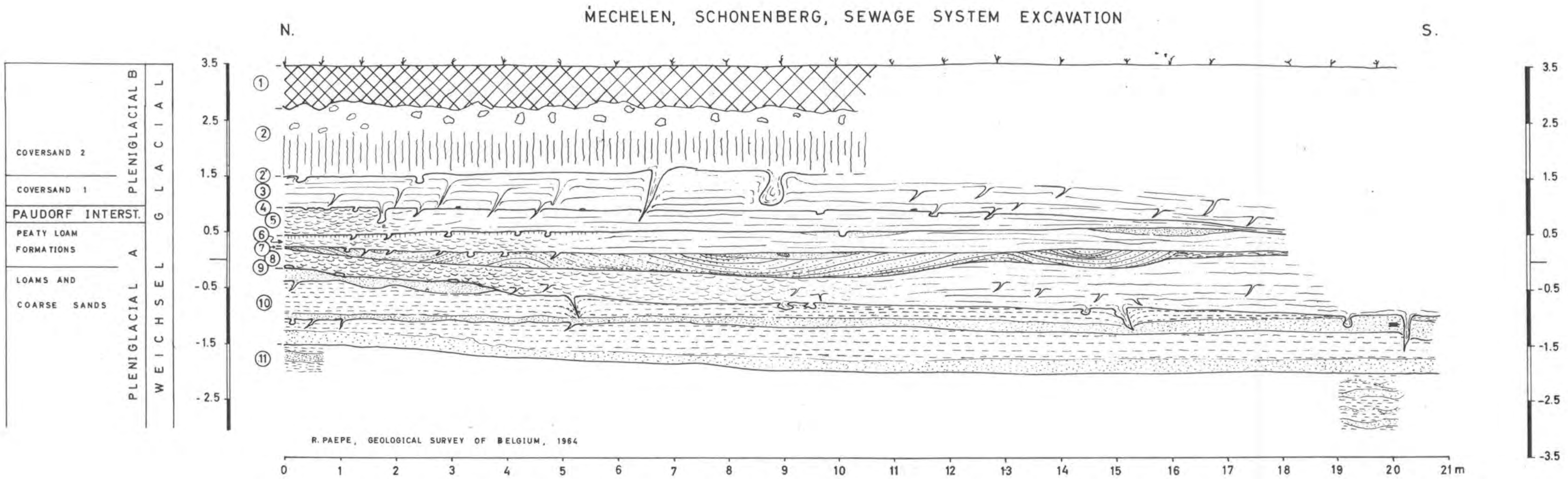
MECHELEN, SCHONENBERG, SEWAGE SYSTEM EXCAVATION
N.
S.
COVERSAND 2
COVERSAND 1
PAUDORF INTERST.
PEATY LOAM
FORMATIONS
LOAMS AND
COARSE SANDS
PLENIGLACIAL B
PLENIGLACIAL A
WEICHSEL GLACIAL
R. PAEPE, GEOLOGICAL SURVEY OF BELGIUM, 1964

FIG. 21

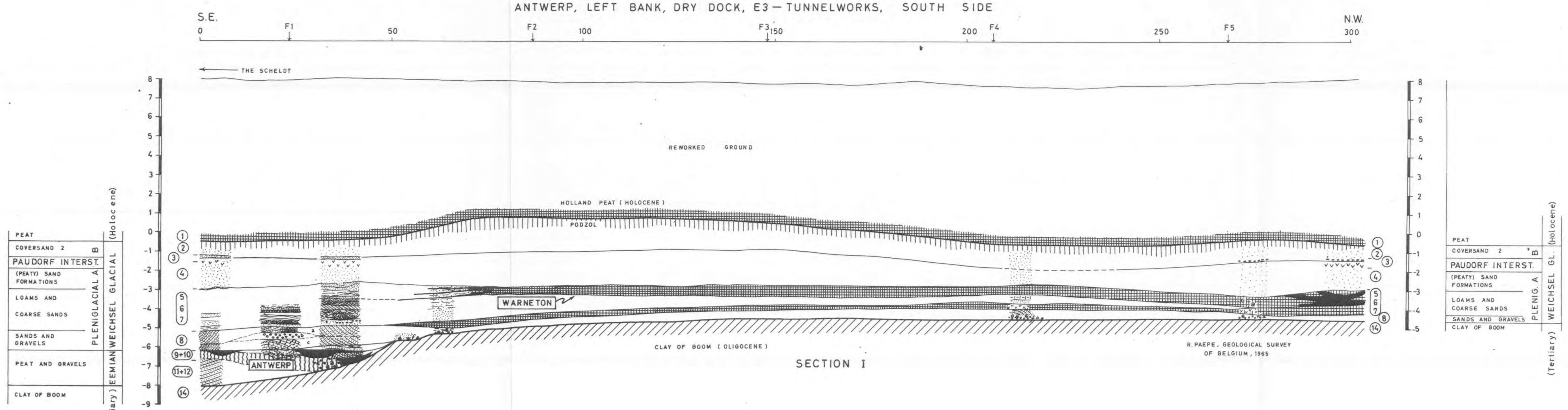

FIG. 22

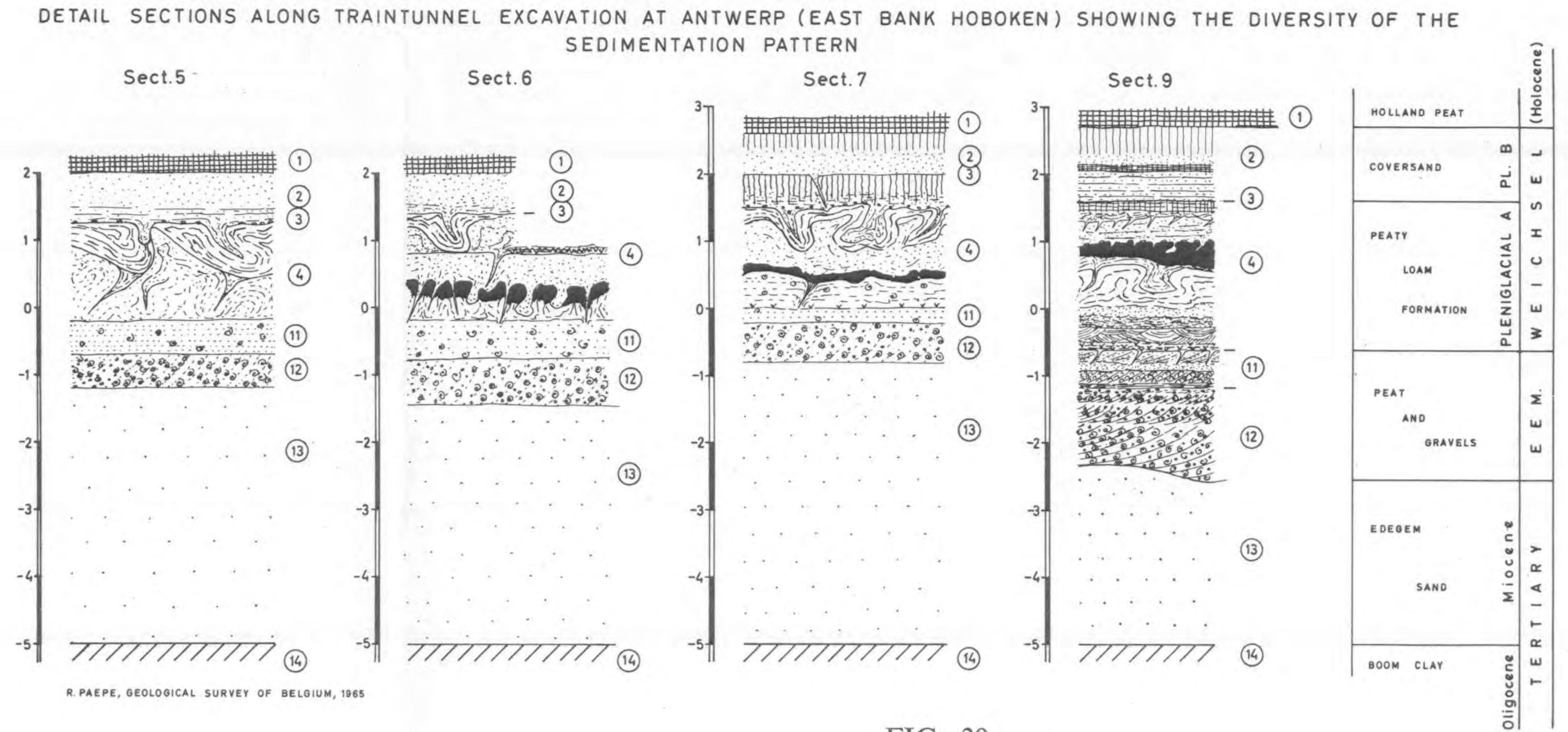

FIG. 30

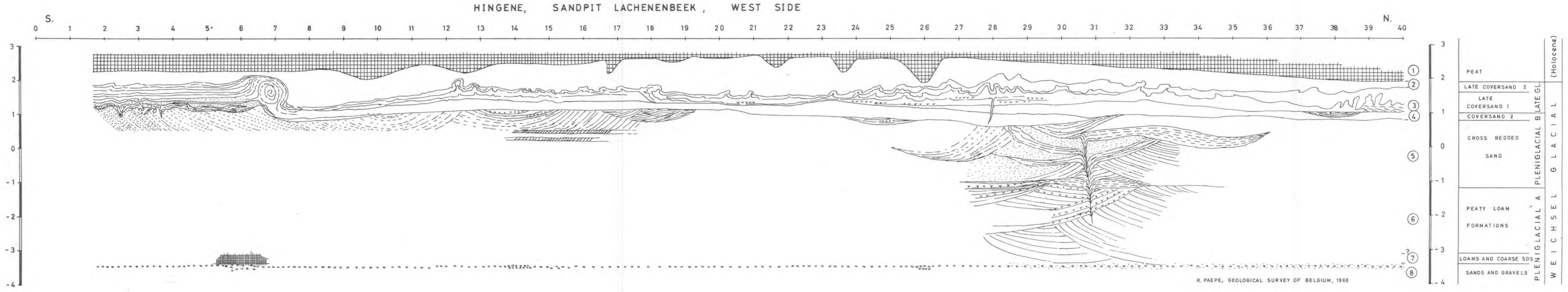

FIG. 23

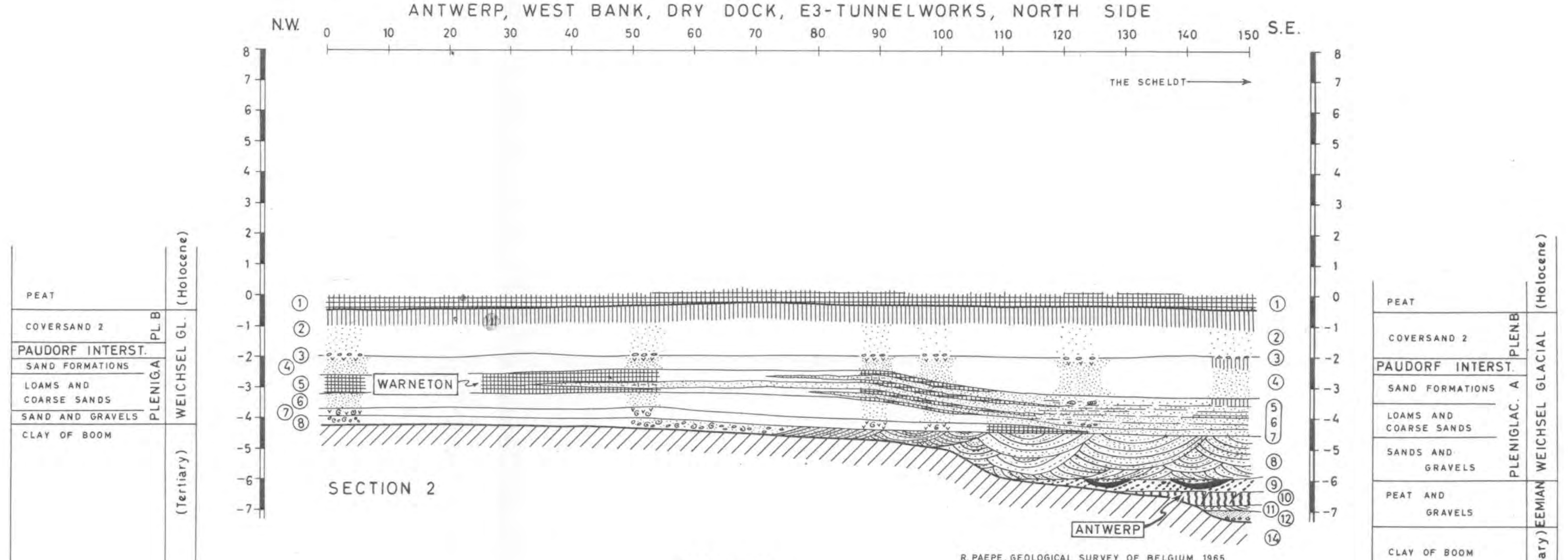

FIG. 24

FIGURES 22-23-24-30

FIG. 25

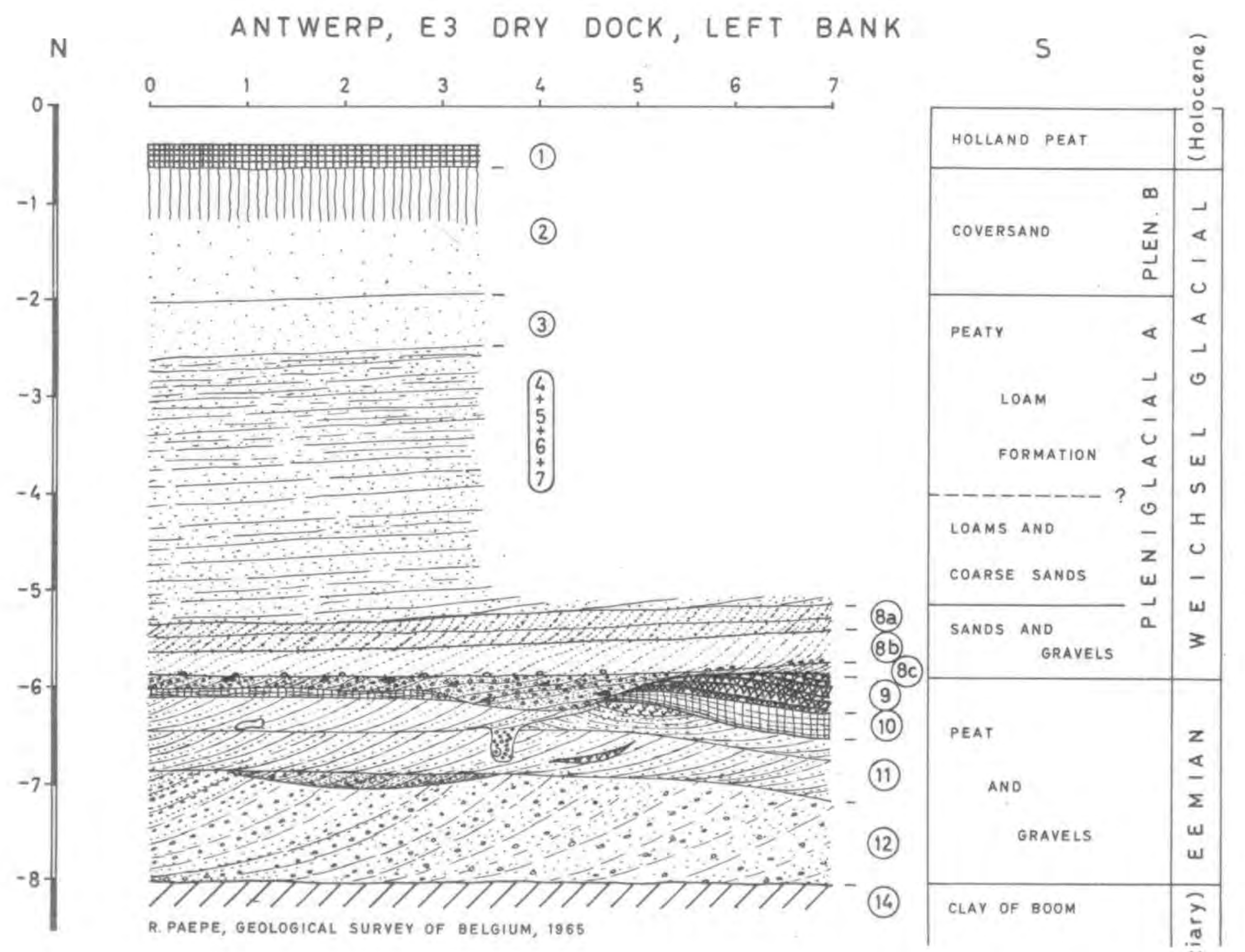

FIG. 26

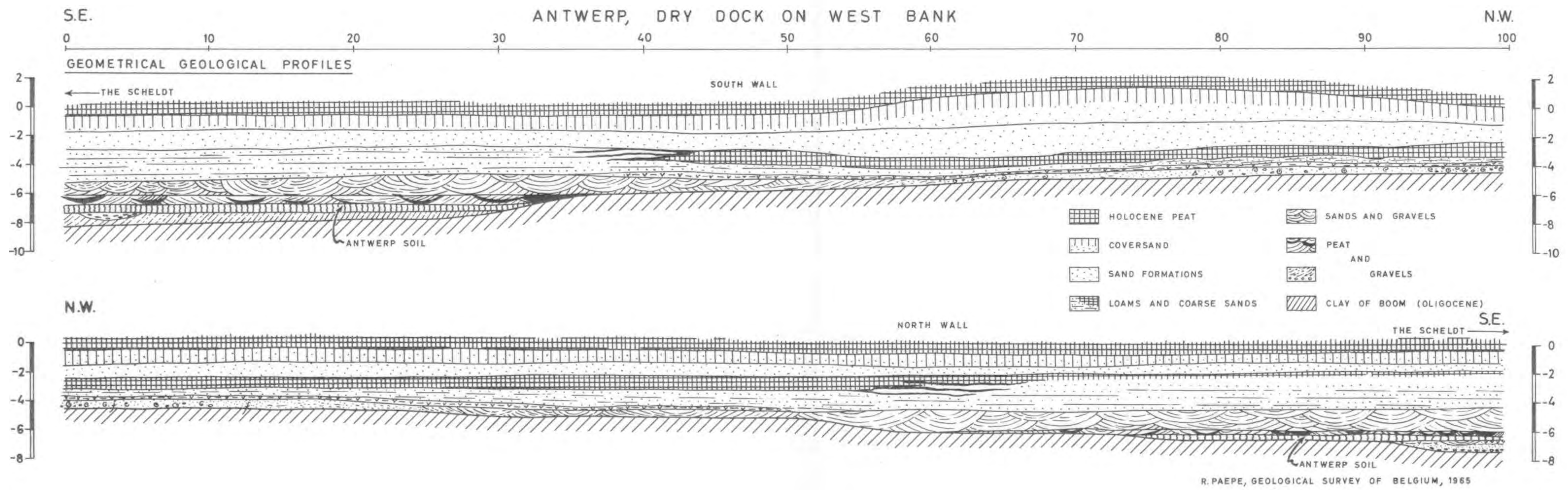

FIG. 27


West
East
WEST BANK
DRY DOCK - ANTWERP
EAST BANK
TRAIN TUNNEL - HOBOKEN
Holocene (Holland peat)
Holocene
Podzol
Peaty loam formations
GrN-4781
32490 ± 440 Y.B.P.
Pleistocene
Miocene
Oligocene
Sands & gravels
The Scheldt
PEAT
COVERSAND 2
PAUDORF INTERST.
SAND FORMATIONS
LOAMS AND COARSE SANDS
SAND AND GRAVELS
CLAY OF BOOM
PEAT AND GRAVELS
PEAT AND RUBBLE
PEATY LOAM FORMATIONS
SANDS OF EDEGEM
GEOLOGICAL SECTION OF E3 - Scheldttunnel excavations
GEOLOGICAL SURVEY OF BELGIUM, R. PAEPE 1965

FIG. 28


E
W
HOBOKEN, TRAIN TUNNELPIT, SOUTH WALL AT ENTRANCE OF TUNNEL
COVERSAND 2
PEATY LOAM FORMATIONS
PEAT AND GRAVELS
SANDS OF EDEGEM
KESSELT
HOBOKEN
HOLOCENE RAVINATION
PEAT
PEATY LOAM FORMATION
SANDS AND GRAVELS
EDEGEM
R. PAEPE, GEOLOGICAL SURVEY OF BELGIUM, 1966

FIG. 29

FIG. 31

FIGURE 31