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AN OUTCROP OF EEMIAN AND EARLY WEICHSELIAN DEPOSITS AT BEERNEM (N.W. BELGIUM)

by G. DE MOOR (*), I. HEYSE (*) and V. DE GROOTE (**)

SUMMARY. - The authors study the sedimentological and paleobotanical characteristics of a continuous succession of Eemian and Weichselian deposits older than 50.000 y. B.P. It forms the major part of the Quaternary cover in a tributary valley of the Upper-Pleistocene Flemish-Valley-Belgian Coastal Plain complex at Beernem. They recognize an alluvial Eemian deposit covering the E4a, E4b, E5 and E6 pollenzones; a quick paleoclimatic transition and Weichselian deposits of a fluvio-periglacial and niveo-colluvial nature with numerous peat layers, one of which is linked with a buried paleopodzol (paleosol of Beernem) and correlated with the Amersfoort interstadial. The pre-Amersfoort peats are of EW I type, the post-Amersfoort ones of a PW type. The numerous syngenetic cryoturbation levels, suggest that all over the pre-Moershoofd Weichselian mean annual temperatures fell below -5°C, at least during successive rather long periods. They contrast the paleobotanical, chronological and sedimentological interpretations.

RESUME. - Les auteurs étudient les caractéristiques sédimentologiques et paléobotaniques d'une succession ininterrompue de dépôts Eemiens et Weichséliens antérieurs à 50.000 a. B.P. Ceux-ci forment la majeure partie du colmatage d'une vallée tributaire du système Vallée Flamande-Plaine Côtière Belge néo-pléistocène à Beernem. Ils reconnaissent un dépôt alluvial Eemien comprenant successivement les zones polliniques E4a, E4b, E5 et E6; une transition paléoclimatique assez brusque et des dépôts Weichséliens de type fluvio-périglaciaire à nivéo-colluvial avec de nombreuses intercalations tourbeuses dont une, passant à un paléosol, est corrélée avec l'Interstade d'Amersfoort. Les tourbes sous-jacentes sont de type EW I, celles sus-jacentes de type PW. Les nombreux niveaux de cryoturbations syngénétiques suggèrent que tout-au-long du Weichsélien anté-Moershoofd, les températures moyennes annuelles descendaient en-dessous de -5°C, tout-au-moins pendant des périodes successives assez longues. Ils discutent la disparité entre interprétations paléobotaniques, sédimentologiques et chronologiques.

SAMENVATTING. - De auteurs bestuderen de sedimentologische en paleobotanische kenmerken van een ononderbroken successie van Eemiaan en Weichseliaan afzettingen, ouder dan 50.000 j. B.P. Ze vormen bijna de gehele opvulling van een zijdal van het Boven-Pleistocene Vlaamse Vallei-Belgische Kustvlakte-systeem te Beernem. Ze herkennen een venig Eemiaan alluvium waarin achtereenvolgens de pollenzones E4a, E4b, E5 en E6 voorkomen, een snelle paleoklimatologische overgang en Weichseliaan afzettingen van fluvio-periglaciale en niveo-colluviale oorsprong met talrijke

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venige tussenlagen waarvan één aansluit op een paleopodzol (paleobodem van Beernem). Deze wordt gekorreleerd met het Amersfoort-Interstadiaal. Oudere venen zijn van het type EW I pollenzone; jongere venen in de afzetting van Beernem, van het type PW. De talrijke horizonten met syngenetische cryoturbaties suggereren dat gedurende het hele pre-Moershoofd Weichseliaan de gemiddelde jaartemperaturen beneden -5°C daalden, tenminste gedurende opeenvolgende vrij lange periodes. De auteurs belichten de contrasten tussen paleobotanische, sedimentologische en ouderdomsgegevens.

1. INTRODUCTION.

The Depression of Beernem (G. DE MOOR et I. HEYSE, 1971), forms a low, subsequent, saddleshaped valley, cutting the hills of Northwestern Flanders and linking the Coastal Plain to the Flemish Valley. At Beernem, the quite flat valley bottom waterdivide culminates at about +11m L.O. and the scoured Eocene substratum is covered by about 10 m of Quaternary sediments whose age, on ground of paleogeographic considerations, cannot be older than Saalian. Since a good while, several, often superposed and cryoturbated peat layers were known to occur within that Quaternary cover, some of them presenting rather moderate, others cold paleobotanic characteristics (R. TAVERNIER, 1940, 1943, 1954; F. STOCKMANS, 1945; G. DE MOOR, 1960; G. DE MOOR, 1969; G. DE MOOR and I. HEYSE, 1971; V. DE GROOTE, 1977).

In 1972-1976 the Mouton-excavation at Beernem (Mexico) cut the entire Quaternary cover. It's situated at 51°09'N. Lat. and 3°21' E. Long., nowadays at about 30 km from the North Sea shore, a distance that during Weichselian time exceeded 300 km. The region is known as tectonic stable, at least since Eemian times (G. DE MOOR and W. DE BREUCK, 1969).

2. LITHOSTRATIGRAPHIC SUCCESSION AND ABSOLUTE AGE.

The lithostratigraphic succession at Beernem (fig. 1) shows a lower peaty complex (I), belonging to the formation of Oostwinkel(*), a thick complex of cryoturbated peaty and sandy layers (II), containing a paleosol remnant (formation of Beernem), a rather thin but heavily cryoturbated loamy-gravely layer (III) and a thin uppermost fine-sandy layer (IV).

C_{14}-ages of 4 successive peat layers in the formation of Beernem proved it to be older than 50.000 y. B.P. (fig. 2), even the uppermost layer (L 8 on fig. 2) dating from more than 50.300 y. B.P. (Gr.7241) (**). Presumably the lower peat complex, covered by the heavily cryoturbated pre-Moershoofd deposits of the formation of Beernem is of Eemian age. This interpretation gets support from the postgenetic character of its cryoturbations and also from the fact that to the East (Zomergem) basal peat in the Depression is interfingering with Eemian silty flood plain deposits of the Flemish Valley and to the West (Assebroek) with intertidal zone deposits of Eemian coastal inlets (formation of Meetkerke). It slightly energes the Eemian intertidal zone deposits, whose top reaches the + 2 m L.O. level (G. DE MOOR en W. DE BREUCK, 1969).

(*) The lithostratigraphic term "formation" is used to indicate an informal lithostratigraphic unit , but not longer being a single sedimentation unit.

(**) Radiocarbon datings worked out by Dr. W.G. MOOK, Groningen, The Netherlands.

3. SEDIMENTOLOGICAL ANALYSIS. (*)

The continental Eemian deposits at Beernem occur between +1 and +3 m L.O. They include an important basal peat layer (V6 on fig. 1) reaching 1 m thickness, and containing flat laying stems in its upper part. That layer is covered with laminated sandy and clayey alluvial sediments (Zo) ending with a less important peat layer (V5). These peat layers have been formed in a swampy alluvial environment surrounded by a forested region.

The formation of Beernem at the Beernem-Mexico section extends between +3 and +10 m L.O.

It consists of a succession of subhorizontal tabular or planar units up to 2 m thick.

Each unit begins with a peat layer whose thickness varies from 5 to 60 cm and laterally is quite changeable. The top of the underlying unit generally presents a more or less thick and developped alteration zone, sometimes a root zone dropping from the peat. As later on pollenanalysis of the peat layers showed the importance of the alteration and root development was related to the paleoclimatic conditions of the peat forming period. A central and most important peat layer (V3 on fig. 1) is linked up with a paleosol of podzol type on slightly higher paleorelief positions. It indicates swampy patches surrounding slight sandy embossments within a valley bottom.

Within each unit the basal peat layer is overlain by dominantly planar stratified laminated sand layers, interfingering with scattered small ripple-laminated gully infillings or macro-ripples.

Those laminated sand layers (indicated as P on fig. 1) are more or less incised by gullies, reaching sometimes a depth of 2 m and even cutting the underlaying peat unit. Hence the uppermost layer of such a unit consists of through-cross stratified sandy gully infillings (marked as G on fig. 1), passing laterally to a laminated sand.

Some laminated sand layers and most of the gully infillings contain lenses and laminae reworked peat. Sometimes, especially in the pre-V3 laminated sand layers, thin lenses or laminae of peat or peaty sand extend over short distances (V4').

Locally slump structures, sand blocks and even peat blocks occur along the banks of the major gullies. Sand blocks seem to have been displaced in a frozen condition mostly by sliding and without long distance transport.

Laminated sands and some gully infillings within the post-V3 sand layer contain laminae of white bleached sand wich proved to originate from the A2 horizon of the V3-paleosol. They refer to erosion and deposition by mainly snowmeltwater runoff.

The laminated sands as well as the gully infillings show numerous levels of, often important, syngenetic frostwedge casts, of droptail structures and of rather small involutions. Large ice wedge casts appear in the largest gully infillings.

The peat layers themselves don't show synchroneous cryoturbation but general and, locally very important, separate regular cryoturbations. Mushroomlike involutions locally 1,5 m height are characteristic as well in the lower, pre V3-part as in the upper, post V3-part. Those cryoturbations seem to have occurred each time after the deposition of a first laminated sand layer (P) covered a peat layer and before gullying started.

Those primary and secondary sedimentary structures afford evidence for a dominance of wet periglacial conditions, starting very quickly after the E6 stage. They also let presume a complex succession of frequent climatic fluctuations. Sedimentologic criteria don't indicate any major difference in paleo-environmental conditions preceding and following the V3- stage. They show a rhytmic sedimentation, each cycle of which consisted of a phase of peat formation, followed by a period of deposition and cryoturbation, itself succeeded

(*) A detailed description of the outcrops has been published by G. DE MOOR and I. HEYSE (1976).

by a period of more energetic gully incision, and finally by one of *fluvio-periglacial gully infilling. A same type of gully incision oc*curred by improvings of temperature conditions, infillings following under worser fluvio-periglacial conditions, as shown by the large ice wedge casts they contain, and which indicate that each cycle lasted perhaps some thousands of years. Pseudomorphs of ice wedges, water extrusion pipes,cryogenetic wedges occur already in the lowest part of the formation of Beernem and even affect postgenetically the uppermost Eemian sands. This can be seen as a prove that quite early in the pre-Moershoofd Weichselian mean annual temperatures fell regularly below -5°C (G.C. MAARLEVELD, 1976) at least for longer periods, with the exception however of a milder period, long enough to allow the development of the V3 peat and podzol. As peat layers don't indicate synchroneous cryoturbations, it's not clear, at least from a sedimentological point of view, if - with the exception of the V3-layer - they represent short slightly milder stages or if they are only sedimentological features in a continuous rather low-energetic fluvio-periglacial and snowmeltwater runoff environment.

Except some thinning of the peat layers and the appearance of some loamy laminae in the uppermost part, no important difference in the sedimentological conditions seem to have occurred neither after nor before the milder V3 stage.

The formation of Beernem has been truncated and covered with a rather thin layer (1 m) of interlaminated silt and very coarse sand. It shows very heavy cryoturbations with frost kettles and deep ice wedge casts (up to 4 m) at regular distances, suggesting a polygonal network. The whole presumes dryer and more extreme periglacial conditions. But, as there is an erosional discontinuity at the base and lack of clear evidence for its age, its belonging to a Pleniglacial Weichselian sequence can only be presumed.

As to the uppermost sandy layer, the lack of large cryoturbations, its primary stratification as well as its occurrence seem to indicate a Late Weichselian, dominantly eolian deposit of local origin.

4. PALYNOLOGICAL ANALYSIS.

The formation of Oostwinkel and the formation of Beernem have been sampled as completely as possible. Successive samples have been taken every 3 cm. A few transitions however could not afford undisturbed samples. The most important successions are localised on fig. 1, giving their lithostratigraphical and also sedimentological position. The generalised pollendiagram (fig. 2) has been drawn according to 9 detailed diagrams.

All samples have been prepared with HCl, HF, KOH and acetolysis, and mounted in glycerol gelly. The studied slides were rich in well-preserved microfossils. The pollen sum P includes all A.P. (trees and shrubs) and N.A.P. (herbs), excluding pollen from water plants and spores, and amounts mostly 500, sometimes 1000. A doted A.P./N.A.P. dividing line (fig. 2) means the pollen sum was lower than 100, or the accounted microfossils (pollen, spores, hystrichosphaerids) were mainly reworked.

The generalised diagram (fig. 2) shows merely selected taxa. All over the diagram, N.A.P. consist mainly of Poacae and Cyperaceae besides Ericales in the upper part of the formation of Oostwinkel and in the lower part of the Beernem formation.

The formation of Oostwinkel is strongly dominated by trees. The tree pollen content reaches more than 90% and shows numerous thermophyles.

A sandy layer (Z, fig. 2) below the V6 peat coincides with a pollenzone dominated by *Corylus* (up to 65% P), *Quercus* and *Alnus* reaching 10-20%P.

The major part of the peat layer V6 forms a second zone, dominated by *Alnus*, which is followed by *Corylus* and the Quercetum mixtum (with

Fig. 1

BEERNEM - Mexico northside

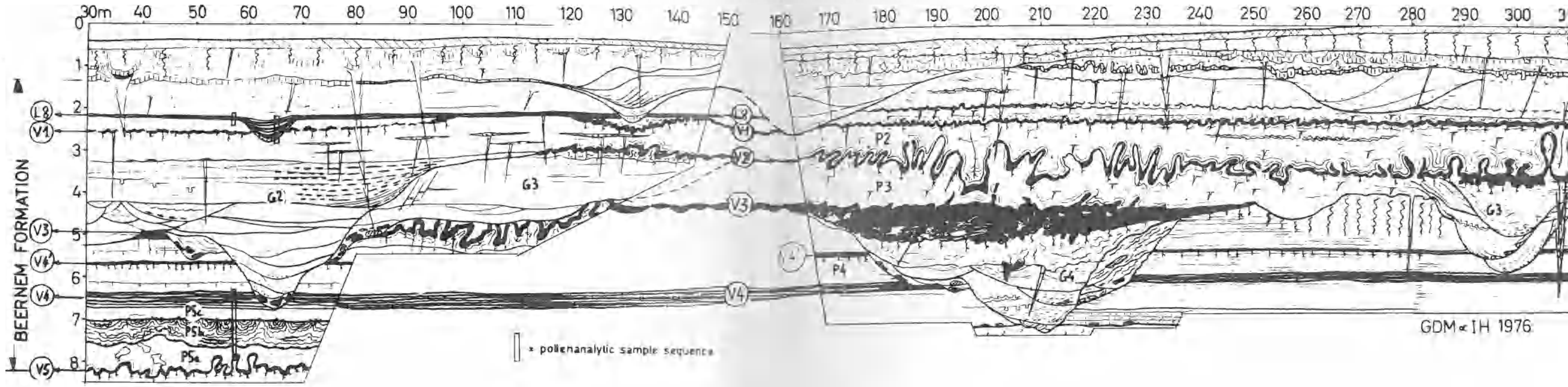
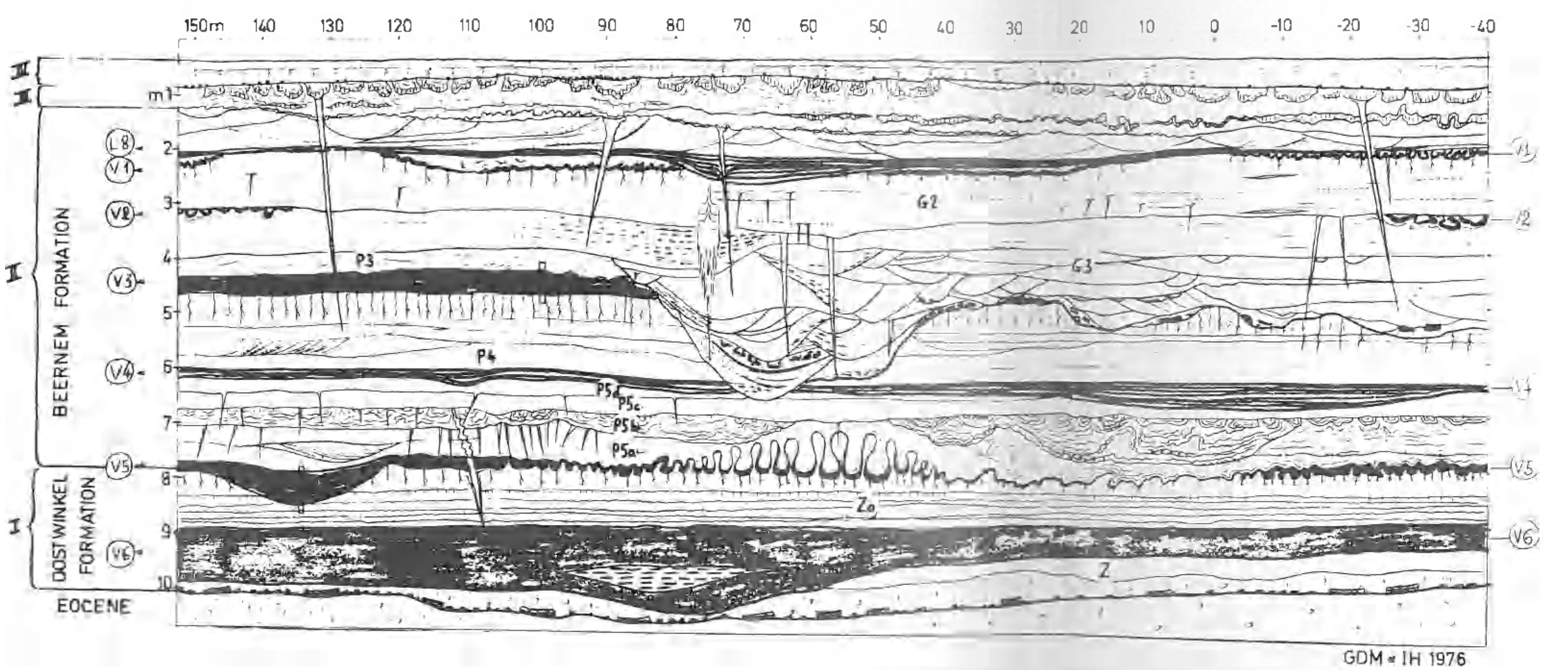


Fig. 1

BEERNEM - Mexico westside



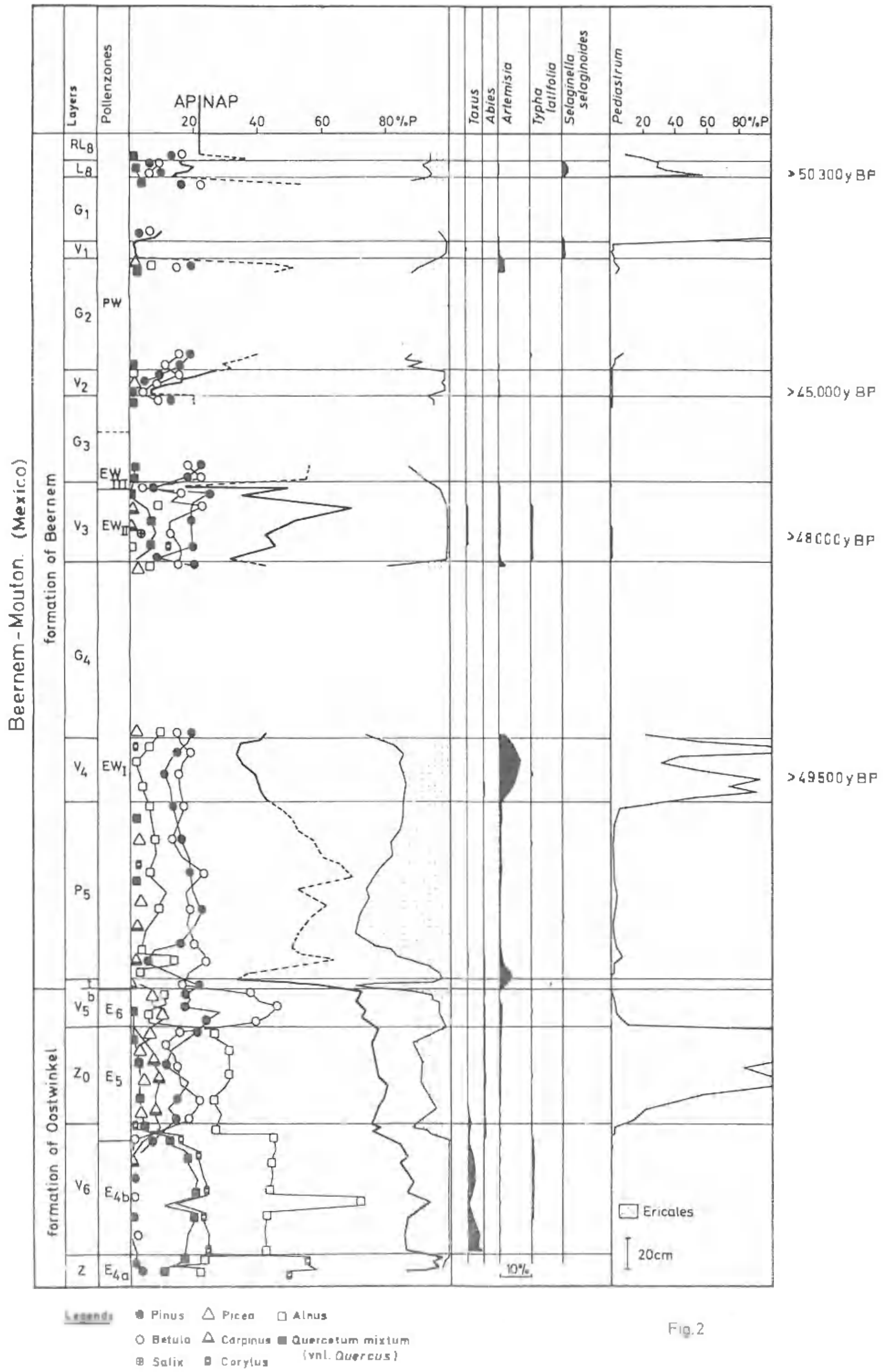

Beernem-Mouton. (Mexico)
formation of Beernem
formation of Oostwinkel
Layers
Pollenzones
AP|NAP
20 40 60 80%P
Taxus
Abies
Artemisia
Typha latifolia
Selaginella selaginoides
Pediastrum
20 40 60 80%P
RLB
LB
G1
V1
G2
V2
G3
V3
G4
V4
P5
V5
Z0
V6
Z
PW
EW III
EW II
EW I
E6
E5
E4b
E4a
>50 300 y BP
>45.000 y BP
>48000 y BP
>49500 y BP
10%
Ericales
20cm
Legend:
Pinus
Picea
Alnus
Betula
Carpinus
Quercetum mixtum (vnl. Quercus)
Salix
Corylus

Fig.2

Quercus and some *Ulmus*, *Fraxinus*, *Tilia* and *Acer*).*Taxus* is present with a maximum value of 5%P.

Both those zones contain regularly *Hedera*, *Lonicera*, *Viscum* and *Ligustrum*. *Ilex* appears continuously in the second one. They represent successively the pollenzones E-4 and E-4_b (zonation after ZAGWIJN, 1961) of the Eemian interglacial forest sequence, the former characterized by the predominance of *Corylus*, the latter by a mixed oak forest besides continuously well represented *Corylus*, locally overshadowed by *Alnus* in this alder-fen peat.

In the upper part of this peat layer V6 *Picea*, *Carpinus* and *Abies* occur continuously;the mixed oak forest and *Corylus* however decrease and both *Pinus* and *Betula* increase.This top of V6 and the overlaying sand Z_0 (fig. 2) form another pollenzone, whose *Carpinus* content reaches about 9% P, *Pinus* and *Betula* both coming second, but *Alnus* still dominating. *Abies* is present throughout this zone, *Taxus* has nearly completely disappeared. Amongst the herbs we notice the expansion of the Ericales and the continuous presence of *Artemisia*. High percentages of *Pediastrum* indicate an underwater deposit, after the alder fen was overflown.

This pollenzone is very similar to the pollenzone E-5 sensu ZAGWIJN, *Carpinus* content however being somewhat lower.

The lower and central parts of peat layer V5 form a next pollenzone, with still 80% tree pollen but now dominated by *Betula*, followed by *Pinus* and *Alnus*. *Picea* amounts to about 10% P. Most thermophilous taxa become very rare or show only a discontinuous presence. Local circumstances seem to have become dryer during this period as the curve of *Pediastrum* drops. This part of the diagram represents the ZAGWIJN pollenzone E-6, the last of the Eemian interglacial. In the uppermost part (V5b on fig. 2) of peaty layer V5, the tree pollen content suddenly drops from 70 to 40%, indicating an open forest. *Pinus* and *Betula* remain the most important trees, *Alnus* and *Picea* only reaching very low values. During this transition from a dense forest to a park-landscape, the Ericales and some light-demanding herbs (e.g. *Artemisia*) got a large extension. The botanic characteristics are very similar to those of the pre-V3 peat layers of the Beernem formation. Although lithostratigraphically still accounted to the Oostwinkel formation, the V5b topzone shows characteristics of an earliest Weichselian vegetation.

On the other hand, the small thickness of the top layer V5b suggests not only a quick vegetational change, but an even fast transition from the mild E6 conditions to the less moderate climate of a Weichselian environment, the more there is no sedimentological evidence of any hiatus neither within, neither on top of peat layer V5.

The pollen sequence of the Beernem formation shows three different parts. In the one below V3, the A.P. content, as well in the peatlayers (V4) as between them (P5), still reaches 40-50%. In the V3 peatlayer it increases to more than 60% P. In the superposed peat layers it decreases to less than 20% P.

The relatively high A.P. content of the sandy layer P5 seems not quite in accordance to the sedimentological indications. At least part of the diagram shows an unreliable A.P./N.A.P. ratio; presumably the layer contains a certain amount of reworked pollen, mostly from laterally outcropping pollenrich V6 peat. High percentages of Ericales indicate a rather heath-like vegetation in surroundings of the deposit.

The peat layer V4 has been formed under wet conditions (Cyperaceae and *Pediastrum*), in a fairly open landscape *(Artemisia, Helianthemum)*.

The layers P5, V4 and G4, as well as the V5b zone, can pollenanalytically be put in the first zone of the last glacial, EW I sensu ZAGWIJN (1961).

The peatlayer V3 shows its own vegetational evolution. The tree pollen increases to a maximum of 70%, then drops again to vålues lower than 20% P. Generally *Pinus* dominates over *Betula*. However, the most striking fact is that here again more thermophilous taxa are continuously present in a pure peat without reworked components : *Quercus* reaches up to 8% P, *Alnus* and *Corylus* slightly less. *Salix* too is well represented, especially in the lowermost part, whereas *Picea* shows a slight increase near the top of this peat. *Myrica* is continuously present. The Poaceae and the Cyperaceae have equal values till the A.P.-maximum; higher up the Poaceae increase to 55% P, the Cyperaceae staying at about 15% P. The lowermost part of the peat shows in addition a well-marked peak of *Equisetum*, whilst *Sphagnum* expands after the A.P.-maximum.

According to its botanical characteristics, its lithostratigraphic position and its connection with a podsol, this peat layer V3 can be correlated with the Amersfoort-interstadial (pollenzone EW-II) as it is known from The Netherlands (ZAGWIJN W., 1961); the pollenanalytical results are quite similar, especially to those from the Moershoofd spot. Similar results have been obtained from a peat layer at Beernem-Miserie, at a distance of about 2 km. (G. DE MOOR, 1960; V. DE GROOTE, 1977), and from Sint-Jan-in-Eremo(I. HEYSE, 1975; V. DE GROOTE, 1977).

This peatlayer V3 corresponds to a climatic amelioration, the first to be recorded here since the Eemian interglacial. That amelioration is shown by the distinct increase of thermophilous trees and of *Typha latifolia*; the latter is again almost continuously present in this peat, and, according to ELLENBERG (1974), is a rather warmth-demanding species.

The superposed peat layers (V2, V1 and L8) all show low A.P.-values, mostly *Pinus* and *Betula*, with some *Salix*. At least part of the *Betula*-pollen is from *B. nana*, and probably part of the willows were dwarf-shrubs too. The other trees are poorly and discontinuously represented, mostly by long distance transport and possibly by some reworking. The Cyperaceae dominate strongly the spectra. *Selaginella selaginoides* is present throughout V1 and L8.

These spectra refer to a wet tundra vegetation with very scarce or no trees, indicating cold and wet climatic conditions. The botanical characteristics of these peat layers do not allow an accurate stratigraphical correlation. Without the C_{14}-datings (more than 50.000 y. B.P.) we should correlate this vegetation with that known from the Meso-Würm (sensu B. BASTIN, 1975), the Moershoofd-, Hengelo- and Denekamp-oscillations from The Netherlands (ZAGWIJN, 1961; VAN DER HAMMEN en WIJMSTRA, 1971) and from Flanders (V. DE GROOTE, 1977), or even with the Late-Weichselian vegetation (sensu VAN DER HAMMEN & WIJMSTRA, 1971).

The sands between these upper peat layers are rather poor in pollen and evidently contain much reworked material.

The whole Beernem formation, at the Beernem outcrop itself, belongs to the Early Weichselian.

Early-Weichselian climatic ameliorations others than the Amersfoort interstadial are not recorded in the Beernem formation at this outcrop. Considering its truncated top, erosion of the upper part of the Early Weichselian deposits still remains possible.

5. CONCLUSIONS.

The Beernem-Mexico section shows a continuous sequence of Eemian and Weichselian sediments in a tributary valley of the paleomorphological Flemish Valley-Coastal Plain system.

The Eemian deposits consist of an alluvial plain facies (formation of Oostwinkel). According to their pollenanalytical content they correspond to an Eemian forest sequence running from about the optimum(E4a) till the end (E6).

Paleobotanically the transition from the E6 to the Weichselian occurs within the uppermost peaty layer of the formation of Oostwinkel. That layer shows EW I pollenzone characteristics and there is no macroscopic discontinuity within that part of the lithostratigraphic unit. Moreover the section affords evidence for a quite quick transition.

The major part of the Weichselian deposits consists of a peat/ sand alternation and dominantly deposited under low-energetic fluvio-periglacial conditions. It shows many levels and types of syngenetic cryoturbations. Peat layers have been cryoturbated after some covering by runoff sands.

The formation of Beernem is older than 50.000 y. B.P. Cryoturbation types and occurrences indicate that quite soon after the end of the Eemian, mean annual temperature fell below -5°C and remained so, at least during successive long periods.

A more important central peat layer, laterally linked with a paleosol (Beernem podzol) indicates that at least one milder interstadial occurred. Sedimentological characteristics don't show any major difference of paleo-environmental conditions before and after that interstadial.

On paleobotanical and C_{14}-age ground, this interstadial corresponds to the Amersfoort interstadial. No other Early Weichselian interstadials have been recorded nor preserved in this sequence.

The pre-Amersfoort peat layers show distinct EW I pollenzone characteristics (A.P. content reaching 40% P.) related to wet but not quite cold climatic conditions. The post-Amersfoort peat layers show a much poorer vegetation of PW type (A.P. content dropping below 20% and mostly even 10% P.) related to distinctly colder climatic conditions. Both layers A.P. content is dominated by *Salix*, *Betula* and *Pinus*.

The pollen content of the fluvio-periglacial and runoff sands shows A.P. peaks and thermophyles. Those pollen are considered as reworked, mainly from the laterally outcropping Eemian and Amersfoort peat layers. This origin is also supported by sedimentological characteristics.

Both, sedimentological and paleobotanical arguments seem not to have reacted simultaneously to major paleoclimatic changes during the pre-Moershoofd Weichselian : the paleobotanic arguments lagging behind the sedimentological ones, at least until the Amersfoort interstadial. Perhaps the sheltered paleomorphological character of the Depression itself has been of some importance.

No sedimentological evidence of Earliest Weichselian deep scouring, characteristic for the major thalwegs of the Flemish Valley (G. DE MOOR, 1974) could be noticed in the Beernem section. Perhaps the distinction between an Earliest and an Early Weichselian has a mere paleomorphological meaning, unless paleobotanical splitting up of the formation of Beernem should afford evidence for that view.

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10 th January 1978

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