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FOSSIL PERIGLACIAL REMNANTS IN THE BEERNEM-MOUTON EXCAVATION IN FLANDERS (BELGIUM)[1]

Abstract

The author presents fossil periglacial structures occurring in an excavation in Beernem, which is situated in a tributary valley of the Upper-Pleistocene Flemish Valley-Coastal plain complex. The valley represents a saddle valley wherein a continuous succession of Eemian and Weichselian (Vistulian) deposits are preserved.

The Eemian deposits are buried by fluvio-periglacial and niveo colluvial deposits with numerous peat layers. An important buried paleopodzol (soil of Beernem) correlated with the Amersfoort interstadial could be established.

Six levels of ice wedge casts give clear evidence of the presence of successive permafrost environments. Numerous cryoturbations, drop soils and thermokarst underline also the deposition in a periglacial environment.

INTRODUCTION

Belgium, belonging to the West European Lowlands and bordering the North Sea, is entirely situated in the periglacial belt of the Saale and the Riss glaciations (Pissart, 1987).

The general elevation is lower than 700 m and based upon the altitude one can distinguish according to De Moor and Pissart (1992) into Low Belgium (between 0 and 100 m) Middle Belgium (between 100 and 200 m) and High Belgium (between 200 and 700 m).

Low and Middle Belgium are essentially linked with the evolution of the Scheldt basin which denudated the underlying Tertiary clayey and sandy substratum (Marechal, 1992) since the end of the Tertiary and during the Pleistocene. A terrace sequence could be recognized by Tavernier and De Moor (1974) covering the entire Quaternary period.

During the Upper Pleistocene important valley complexes were scoured in the underlying Tertiary substratum by the Scheldt river and its tributaries and also by the Yzer, which drained the waters to the North Sea. The Coastal valley complex and the Flemish valley complex are the most striking ones. In both valleys Eemian marine deposits are preserved (De

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Moor and Heyse 1974; Heyse 1975). The Flemish Valley however is the most important key valley of the Scheldtbasin wherein essentially aggradational terraces are buried.

The excavation of the Beernem-Mouton excavation in the Saddle Valley of Beernem between the Coastal Plain and the Flemish valley is studied and analysed.

THE SADDLE VALLEY OF BEERNEM

The "Depression of Beernem" (De Moor, I. Heyse, 1971), also called previously the "Depression of the canal Gent-Brugge" (De Moor, 1960), forms a low subsequent saddleshaped valley cutting the hills of North--Western Flanders and linking the Coastal Plain to the Flemish Valley. At Beernem the quite flat valley bottom waterdivide culminates at about +11 m and the sandy Eocene substratum is covered by about 10 m of Quaternary sediments.

In 1972–1976 the Beernem-Mouton-excavation at Beernem (Mexico) was for the first time digged out to such a depth that the entire Quaternary sequence was outcropping in the axis of the paleovalley. This offered the exceptional opportunity to study the entire sequence at the most optimal geomorphological location. The pit coordinates are 51°09' N Lat. and 003° 21' E Long.

The distance nowadays from the North Sea shore is of the order of 30 km, during the Weichselian time however that distance exceeded 300 km.

A first report of the excavation was described by Heyse 1975. Palynological analysis were done by V. De Groote in 1977. Further results were published by G. De Moor, I. Heyse 1976; V. De Groote 1978; G. De Moor, I. Heyse, V. De Groote 1978; G. De Moor 1981.

Additional inedited data were also collected at several occasions by I. Heyse between 1976 and 1999 in the immediate vicinity during the improvement works along the canal GentBrugge. A schematic overview of the section is now presented.

ANALYSIS OF THE BEERNEM-MOUTON EXCAVATION

THE LITHOLOGICAL SUCCESSION

A serie of 33 well distinct layers (L1–L33) numerated from old to young (see Fig. 1) are recognized and schematised in the following table. The inventorisation of the lateral facies was also facilitated by the presence of numerous distinct peat layers which could be used as marker layers:

Lithological succession of the Beernem–Mouton excavation

Table I

Layers	Sedimentological characteristics
L1	Green glauconite rich fine to medium fine sands; locally sandstone intercalations present (not exposed); Tertiary substratum (Eocene marine deposit)
L2	Gravel pavement of platy sandstones, rounded and broken silex elements, some small quartz pebbles; base lag gravel of quaternary deposits; locally disturbed by sandinvolutions
L3	Fine grey-green sands, some glauconite; reworked Tertiary sands
L4 (V6)	Compact peat with well preserved wood fragments and tree-stems in the upper part (to 1 m) locally clay intercalations incorporated in the peat (small gullies or channels); drown Eemian forest
L5	Fine sands grey light greenish, small undulating microlaminae with microdropsoils: ice wedge cast at the top (IW1); weakly developped soil at the top
L6 (V5)	Continuous peat (10 cm), locally undulated, thicker unit in small channels); well preserved rootfragment of the peat at the base level; strongly disturbed in wave pattern cryoturbations
L7	Fine grey sands, laminated; eroded frost wedge level at the top zone
L8	Fine sands laminated; top zone loam-sand lamination; trough cryo-turbations, thermokarst
L9	Fine sands, planar structure and gullies and channels with trough lami- nation filled with some coarser sands; syngenetic frost wedges
L10 (V4)	Continuous horizontal peat, locally thicker in depressions; multi-laminated, not disturbed
L11	Fine grey sands, laminated and planar structures, locally gullies and some coarser sands
L12	Discontinuous peaty lamina
L13	Fine sands, laminated, planar structures and shallow gullies with some coarser sand; top zone ice wedge level (IW2); distinct soil profile (soil of Beernem), top zone eroded
L14	Coarse sand in complex interravinating channel system, trough sedimentary structures; disturbed slope deposits in oversaturated sands

L15 (V3)	Continuous thick peat layer colmatating a channel system (L14)
L16	Fine sands, planar, lateral sandy channels system with coarser sands; frost level at the top
L17	Fine laminated sands; ice wedge level (IW3) at the top
L18	Fine and coarse sands in complex interravinating channel system
L19 (V2)	Continuous peat layer; locally well developped and overlying an older channel system (L18); well developped cryoturbation troughs
L20	Fine sands, laminated; syngenetic frost wedges at different levels
L21	Fine sands with syngenetic ice wedge level (IW4) and water extrusion structure
L22 (V1)	Continuous peat layer; cryoturbated and disturbed by bioturbations
L23	Fine sands laminated; syngenetic frost wedges
L24	Fine sands, laminated, locally planar shallow gullies with erosive basis
L25 (V0)	Silty laminated peat; laterally thicker developped in depressions
L26	Fine sands laminated; syngenetic frost wedges
L27	Fine sands, erosive baselevel; syngenetic frost wedges at different levels; postgenetic ice wedge level (IW5)
L28	Fine sands; syngenetic frost wedges; postgenetic ice wedges (IW6)
L29	Loam-sand complex; intensively cryoturbated in kettles
L30	Fine lag gravel veneer; cryoturbated in troughs; polar desert
L31	Fine homogenous sand; aeolian coversands
L32	Fine horizontal lag gravel veneer; frost wedge level; polar desert
L33	Fine homogenous sands; aeolian coversands; small frost cracks or sandcracks; Holocene podsol soil in the topzone

FIELD ILLUSTRATIONS

The excavation was realized during a temporarely lowering of the groundwater table due to continuous pumping. Because the observation period was limited in time, an inventory of the outcropping deposits was also desirable by means of selected photographs. A databank of sedimentological features could be established. The exposed walls were carefully examined and small scale as well as large scale phenomena were inventorised.

A selection of some photographs illustrates very well the variety and the richness of the sedimentological features (all the photographs are taken by the author during several field campaigns):

LITHOSTRATIGRAPHIC TERMINOLOGY

The quaternary layers are classified into 4 lithostratigraphic formations (see Fig. 1):

Formation of Oostwinkel
Formation of Beernem
Formation of Eeklo
Formation of Maldegem

The specific characteristics and description is given hereafter.

SEDIMENTOLOGICAL ANALYSIS

The quaternary basegravel is a distinct marker between the tertiary substratum and the overlying quaternary deposits. It represents a lag gravel originated by intense quaternary denudation as a result of the landscape scouring and lowering since the regression of the Tertiary seas. This overall denudation modelled the main geomorphological characteristics of the hilly relief in Flanders. More particularly, the saddle valley of Beernem was sculpered as a subsequent valley system at the foot of the Bartonian cuesta.

The continental Eemian deposits grouped into the *formation of Oostwinkel* at Beernem occur between +1 and +3 m (Level of Ostend L.O.).

The important basal peat (L4–V1) reaches 1 m thickness is very continuous spreaded and is characterized by a high number of flat laying stems especially in its upper part. Undoubtedly it has been formed in a swampy alluvial environment in the valley bottom of the depression of Beernem and it was certainly surrounded by a forested region. At that time the Eemian sea was nearby as it is prooved by the presence of marine wadden deposits at a level of +1 in the vicinity of Brugge (Heyse 1970). Finally the peat layer was entirely buried by sands originating from the

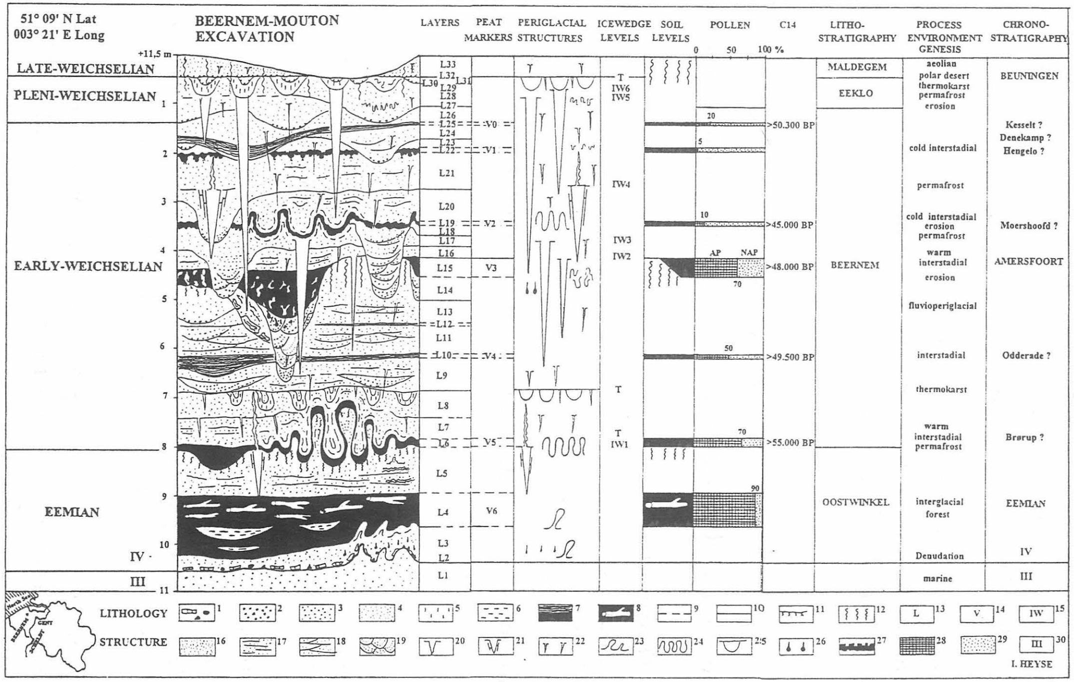

Fig. 1. Beernem-Mouton excavation. Legend lithology: 1. sand, silex, quartz, gravel; 2. gravel; 3. coarse sand; 4. fine sand; 5. loam/silt; 6. clay; 7. peat/peaty; 8 peat/wood; 9 accumulation level; 10. erosive level 11. vegetation roots in situ; 12. soil horizon; 13. lithological unit; 14. peat marker; 15. homogeneous sand. Legend structures: 16. homogeneous; 17. laminated sand; 18. planar structure; 19. trough structure; 20. ice wedge/sand wedge; 21. ice wedge with blocky structure; 22. frost wedge; 23. upward involution; 24. wavelike involution; 25. kettle depression/thermokarst; 26. drop soils; 27. irregular cryoturbation; 28. arboreal pollen; 29. non arboreal pollen; 30. Tertiary substratum

adjacent slopes where the Tertiary- and Quaternary sands are reworked and deposited at short distances.

The *formation of Beernem* extends between +3 and +9 m L.O.

It consists of a succession of subhorizontal tabular or planar sand units alternating with peat layers whose thickness varies from 5 to 60 cm. The most important peat layer L15–V3 is linked with a paleosol of the podzol type which is developped on slightly higher paleorelief sandy environment.

The other peat layers L6–V5; L10–V4; L19–V3 are less developped but are also linked laterally to small gully systems wherein the peat reaches its maximum thickness in swampy conditions.

Some laminated sand layers and most of the gully infillings contain lenses of reworked peat fragments.

The uppermost peat layers L22–V1 and L25–V0 are thinner and remarkably horizontal in extension;

The different sand layers L7, L8, L9, L11, L13, L16, L17, L20, L26 form units with similar sedimentary structures. They form planar stratified laminated sand layers interfingering with scattered small ripple-laminated gully infillings or macro-ripples. The deposition has been established in a similar environment and has been formed by several sedimentation cycles.

Clear evidences of gully and channel sediments are recognized in the layers L14, L18. They reach a depth of more than 2 m and erode clearly the underlying units. They forms undoubtedly the more active main channels during increased runoff. Distinct trough-cross stratified sandy gully infillings can pass laterally to laminated sand.

The *formation of Eeklo* extends essentially between +9 and +10. It is poorly represented by the layers L27, L28 and L29, L30, L31. It is entirely sandy but it has more or less similar sedimentological structures as in the Beernem formation. The peaty units are lacking completely. This formation finalizes the subaquateous colmatation of the saddle valley of Beernem. The layers L30, and L31 have been undergone more aeolian influence.

The *formation of Maldegem* represents a superficial blanket of less than 1 m thickness. L32, L33 is characterized by an erosive base level underlined by a thin lag gravel probably enriched in a polar desert by intense deflation. The overlying well sorted sands are homogenous, fine laminated and show all characteristics of an aeolian sediment.

PALEO-ENVIRONMENT AND GEOMORPHOLOGY

The Weichselian or Vistulian deposits contain 6 levels of ice wedge casts. In the lower sand units ice wedges are about 1 m deep while in the upper sand units large ice wedges can reach depth of up to 4 m. Some ice wedges show clear evidence of water extrusion from melting indicating clear evidence of the existence of permafrost and related influence of the presence of an active layer. The successive distinct levels of icewedges suggest at least the existence of a discontinuous permafrost.

Most icewedge casts are characterized by a central vertical laminar infilling associated by lateral cone in cone infilling and also by a lateral blocky structure due to microfaulting as a result of a slight vertical subsidence and displacement of the random sediments. The magnitude of the setting is of the order of centimeters to decimeters. Analogous descriptions are published by several authors (TAVERNIER 1944; MACAR and VAN LECKWIJCK 1957; FRENCH 1976; PISSART 1976, 1987; VANDENBERGHE 1983; GOŹDZIK 1994, 1995).

Locally slump structures, sand blocks occur along the banks of the major gullies. Sand blocks have been displaced in a frozen condition at short distances probably by sliding.

Laminated sands as well as the gully infillings show numerous levels of important, syngenetic frostwedge casts. Locally drop tail structures and small involutions are also common.

The peat layers themselves show cryoturbations after they were buried by sand deposits. Regular cryoturbations and mushroom like involutions locally up to 1,5 m are characteristic as well in the lower as in the middle sand units.

A periglacial wet environment in combination with a permafrost is evident. A succession of permafrost aggradation followed by a degradation of the permafrost is likely but it is difficult to estimate these cycles more accurately.

The formation of Beernem has been truncated and covered with a rather thin layer (1 m) of interlaminated silt and 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. As there is an erosional discontinuity at the base and lack of clear evidence for its age, its belonging to the the Pleniglacial Weichselian sequence can only be presumed.

Gradually more dryer conditions seem to be dominant in the top zone (formation of Eeklo).

As to the uppermost sandy layer (formation of Maldegem), the lack of large cryoturbations, its primary stratification as well its geomorphological occurrence seem to indicate a Late Weichselian age in a dry periglacial environment.

ABSOLUTE AGE

C^{14}-ages of 4 successive peat layers in the formation of Beernem worked out by Dr. W. G. MOOK in Groningen (The Netherlands) indicate an age of more than 50,000 years B.P.

L25–V0: 50.300 years B.P.
L19–V2: >45.000 years B.P.
L15–V3: >48.000 years B.P.
L10–V4: >49.500 years BP.
L4–V5: 55.000 years BP

The absolute dates point to the interpretation of an Early Weichselian (Early Vistulian, age for the Beernem formation.

The basal peat in the Oostwinkel formation is geomorphologically situated in flood plain deposits interfingering with Eemian coastal marine wad deposits (Formation of Meetkerke). Consequently an Eemian age is presumed which coincides with the pollenanalytical results.

POLLEN ANALYSIS

The formation of Oostwinkel and the formation of Beernem have been sampled as complete as possible and the results are given in the generalised diagram figure.

The pollen analysis was done by Dr. V. De Groote who prepared the samples in the laboratory and determined the pollens sum P including all A.P. (arboreal pollen, trees and shrubs) and N.A.P. (non arboreal pollen, herbs) on the basis of mostly 500 or sometimes 1000. Waterplants and spores are excluded. To facilitate the comparison between the peat layers, the percentage of AP/NAP ratio is visually incorporated into the figure of the excavation.

The f*ormation of Oostwinkel* is strongly dominated by trees. The tree pollen content reaches more than 90% and shows numerous thermophyles. It can be subdivided into 3 zones:

Lower pollen zone: the sandy zone (L3) under the peat layer coincides with a pollen zone dominated by *Corylus* (up to 65%) and *Quercus* and *Alnus* reaching 10–20%. This is correlated with the pollen zone E–4 after Zagwijn).

Middle pollen zone: covering the major part of L4–V6, tree pollen more than 90% dominated by *Alnus*, which is followed by *Corylus* and the *Quercetum mixtum Quercus*, some *Ulmus, Fraxinus, Tilia* and *Acer* and *Taxus*. This is correlated with the E–4b after Zagwijn.

Upper pollen zone: covering the topzone of the peat layer L4–V6, the sand layer L5; This zone with tree pollen of 80% is characterized by *Picea, Carpinus* and *Abies*; the mixed oak forest and *Corylus* decrease and both *Pinus* and *Betula* increase. High percentages of *Pediastrum* is indicates an underwater deposit. This pollen zone is very similar to the pollen zone E–5 sensu Zagwijn.

Top pollen zone: covering the peat layer L6–V5. Most thermophilous taxa become very rare and the AP pollen drops from 70% to 40%. *Betula* becomes dominant in association with *Pinus* and *Alnus*. It is correlated with E–6 of the ZAGWIJN pollen zone.

The entire Oostwinkel formation.

The pollen sequence of the *Beernem formation* shows three different parts.

The peat layer L10–V4 with a moderate tree pollen percentage of 40–50% is dominated by *Betula* and *Pinus*, a high percentage of *Artemisia* and *Pediastrum*, which suggest a formation under wet conditions (*Cyperaceae*) in a fairly open landscape (*Artemisia, Helianthemum*) and it can be put in the first zone of the EW I of ZAGWIJN, 1961.

The peat layer L15–V3 illustrates a tree pollen curve (dominance of *Pinus* and *Betula*) of maximum 70% followed by a dropping down to 20%. Thermophilous trees such as *Quercus, Alnus* and *Corylus* are also present up to 8%. DE GROOTE correlates this with the Amersfoort-interstadial EW–II of ZAGWIJN. This climatic amelioration is also recorded by the distinct soil profile.

The peat layers L19–V2; L22–V1 and L25–V0 show all low AP-values, mostly *Pinus, Betula* and some *Salix*. At least part of the *Betula* pollen is from *Betula-nana* and part of the willows were from dwarf-schrubs. The *Cyperaceae* dominate strongly the spectra and *Selaginella selaginoides* is also present especially in the 2 upper peat layers. These spectra refer to a wet tundra with scarce or no trees. Palynologically the spectra ressembles the Meso-Würm (sensu BASTIN, 1975) or the Moershoofd-, Hengelo-, Denekamp oscillations (ZAGWIJN, 1961; VAN DER HAMMEN *in*: WIJMSTRA, 1971) but the C^{14} age of >50,000 is not in accordance with these correlations.

The whole *Beernem fomation* is considered as Early Weichselian (Early Vistulian).

In the formation of Eeklo considered as Pleni–Weichselian (Pleni--Vistulian) no palynological data are available, neither in the overlying formation of Maldegem of Late Weichselian age.

SYNTHESIS OF THE BEERNEM–MOUTON EXCAVATION

(See figure 1)

The synthesis of the Beernem-Mouton excavation is presented by a simplified drawing illustrating the entire sequence of deposits in annex. Information is given about the chronostratigraphy Eemian, Early-Weichselian (Early-Vistulian), Pleni-Weichselian (Pleni-Vistulian), Late-Weichselian (Late-Vistulian) as well as the lithostratigraphy (formation of Oostwinkel, formation of Beernem, formation of Eeklo, formation of Maldegem). The detailed succession of the inventory of the layers (L1 to

L33) as well as the nature of some layer boundaries (erosion versus sedimentation), the indication of the most relevant peat layers easily used as reference layers or marker layers (V0, V1, V2, V3, V4, V5, V6) are indicated in different columns.

A schematic overview of the most typical periglacial features and their exact location in the deposits (levels of eroded icewedge casts, cryoturbations, involutions). More specifically 6 levels of icewedge casts could be examined.

Indications of paleosoils (soil of Beernem) partly eroded and partly syngenetic with some peat layers.

Some deductions are given in relation to the genesis of the layers and some environmental consequences (vegetation cover, presence or absence of permafrost, thermokarst, interstadial periods, paleoclimate).

Also the amount of arboreal pollen versus non arboreal pollen elaborated by V. DE GROOTE is schematic indicated and permits some paleoclimatological deductions.

The absolute C^{14} datings, worked out by MOOK of Groningen, are also incorporated in the scheme. Besides some process and environmental indications a tentative correlation with some interstadials mentioned in the literature is also mentioned.

PERIGLACIAL ENVIRONMENT IN BELGIUM AND THE SIGNIFICANCE OF THE BEERNEM-MOUTON EXCAVATION IN FLANDERS

The *periglacial environment in Belgium* during the quaternary has been reported by TAVERNIER for the first time in 1944–1945 and since this bench paper numerous scientists have found evidences of fossil cold environment in Belgium.

The University of Liège concentrated its efforts mainly in High Belgium (MACAR, VAN LECKWIJCK, 1957; PISSART, MACAR 1963; MACAR, PISSART, 1987).

The University of Leuven under the direction of GULLENTOPS was more interested in Middle Belgium (Loam belt) and East Belgium (Campine and Maas) although also some work has been done in High- and Low Belgium. (PAULISSEN, 1973; GULLENTOPS F., PAULISSEN, E., VANDENBERGHE, J., 1981).

The University of Gent concentrated its research essentially in Low and Middle Belgium. More specifically the Scheldt basin, the Flemish Valley and the Coastal Plain got special attention (TAVERNIER, MARECHAL, DE MOOR, HEYSE).

Also PAEPE from the Geological Survey of Belgium and the University of Brussels did intensive research about the Quaternary (PAEPE, VANHOORNE, 1967.

Comparison with adjacent countries especially The Netherlands and France are frequent, MARECHAL, MAARLEVELD 1955; GULLENTOPS *et al.* 1981; VANDENBERGHE 1983; VAN VLIET-LANOË 1994.

The *Beernem-Mouton excavation* reveals an overwhelming database about the entire last glacial period (Weichselian or Vistulian) in Belgium. The cryoturbation types occurring in Beernem are comparable with the typical fossil periglacial structures published in different textbooks and papers such as WASHBURN, 1973; FRENCH, 1976; HEYSE 1983; HARRIS, FRENCH, & HEGGINBOTTOM, 1988; VAN EVERDINGEN, 1994.

The underlying Eemian deposits mark very clearly the under chrono-stratigraphic limit. There is no question about the stratigraphic former interglacial.

The fluvioperiglacial sandy sediments with numerous icewedge casts and syngenetic frostwedges are clearly deposited during cold climatological conditions with presence of a permafrost. The peat layers with high arboreal pollen indicate undoubtedly interstadial periods. The most important interstadial corresponds with the L15–V3 peat layer. Besides the high pollen content additional geomorphologic arguments of the paleo-landscape could be elucidated such as fluvioglacial channel complexes, soil levels and marshy areas.

More detailed chrono-stratigrahic interpretation of the section remains tentative. Based upon pollen analysis the question arises to the existence of the Brörup, Odderade as mentioned by different authors. Also the more cold interstadials of Moershoofd, Denekamp, Hengelo and Kesselt can not be excluded. Anyhow the L19–V2 and the L22–V1 and the L25–V0 are characterised by low AP content which point to an interpretation of a pleniglacial age but this is not in accordance with the C^{14} data. The limit between the Early-Weichselian and the Pleni-Weichselian can still be improved by additional observations.

The deterioration of the paleoclimate in the top zone of the Pleni-Weichselian is clearly indicated as well by the pollen content as by the number and the size of the ice wedge casts.

The upper limit of the Pleni-Weichselian sequence is sharply cut by the Beuningen gravel, which is accepted as the limit between the Pleni-Weichselian and the Late-Weichselian (L32). Paleogeomorphologically the environment was changed into a cold and dry desert.

The presence of the cryoturbated L30 lag gravel with analogous genesis suggests still some influence of thermokarst phenomena.

CONCLUSIONS

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

The Oostwinkel formation corresponds with Eemian deposits consisting of an alluvial plain facies in association with a dense forest of E4a to E6 age. Paleogeomorphologically it forms the continuation of a marine Eemian coastal plain at short distances (few kilometers).

The Weichselian sequence shows, a large number of fossil periglacial se- dimentary structures, such as syngenetic and postgenetic ice wedge casts, frost wedges, icemelt structures, upward and downward involutions, thermokarst depressions, circular kettle form-like depressions, regular wa- ve like involutions, chaotic cryoturbations, dropsoils and a variety of small scale distorsions.

Six independant ice wedge casts are recorded, 4 of them are syngenetic in the formation of Beernem and 2 are associated with the formation of Eeklo. The dimensions of the ice wedges are more distinct in the top zone while the involutions are more impressive in the lower sequence.

The evidence of the Amersfoort interstadial is deducted from C^{14} data, pollen results, the presence of an important soil and the paleogeo- morphological context.

The pre-Amersfoort peat layers show distinct EW I pollen–zone–cha- racteristics related to wet but not quite cold conditions. The post-Amers- foort peat layers show a much poorer vegetation and are related to colder climatic conditions.

The succession of 6 ice wedge casts underlines the presence of perma- frost conditions since the Early Weichselian probably discontinuous in time but with an increasing importance towards the top sequence.

The cryoturbation types indicate average annual temperatures below –5°C during successive long periods.

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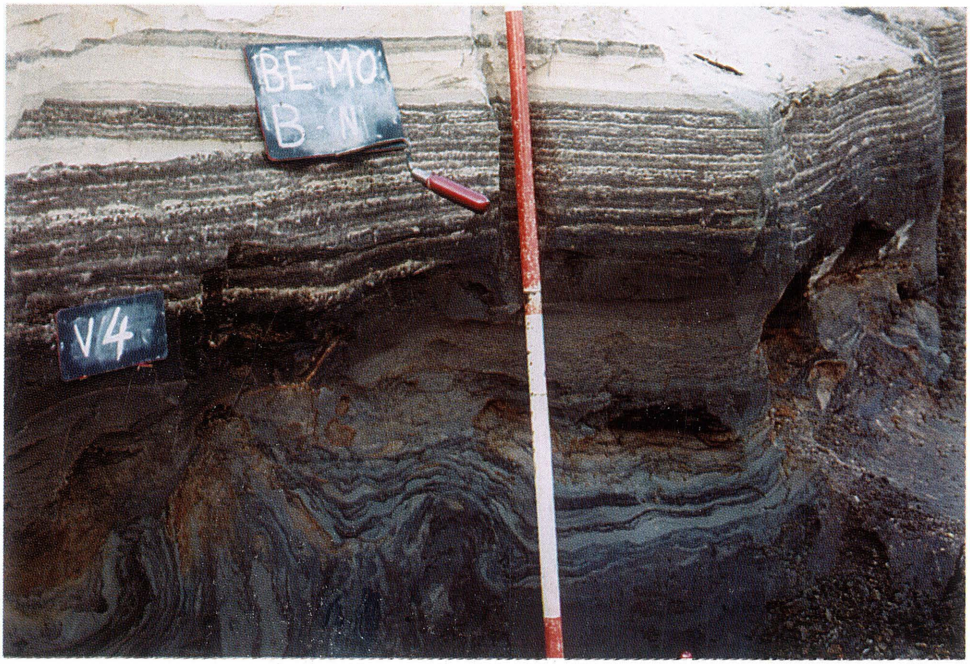
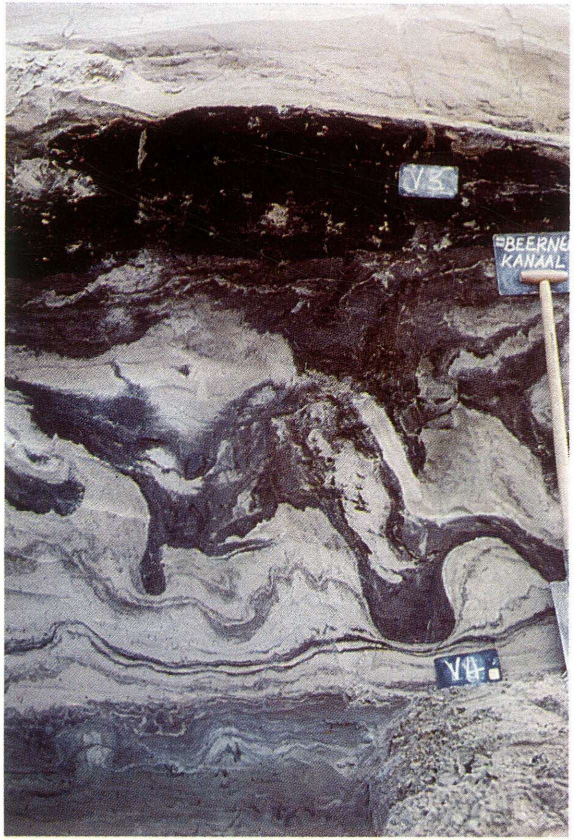
Pl. 1. Eemian peat (L4–V6) overlying by a multilaminated sand deposit (L3), laminae with reworked peat debris from V6; ice wedge level associated with vertical involution due to water escape structure

Pl. 2. Upward involution of greenish reworked Tertiary sand; downward involution of peat layer (L6–V5), numerous levels of micro involutions of syngenetic small scale peaty drop soils in sand (L5)

Pl. 3. Regular large scale wavelike involutions, synchronous upward and downward displacement in an oversaturated environment (cryoturbations in active layer)



Pl. 4. Horizontal clayey laminated peat sequence (L10–V4) overlying disturbed green reworked tertiary sands; the peat sequence evolves in a multilaminated sandy deposit

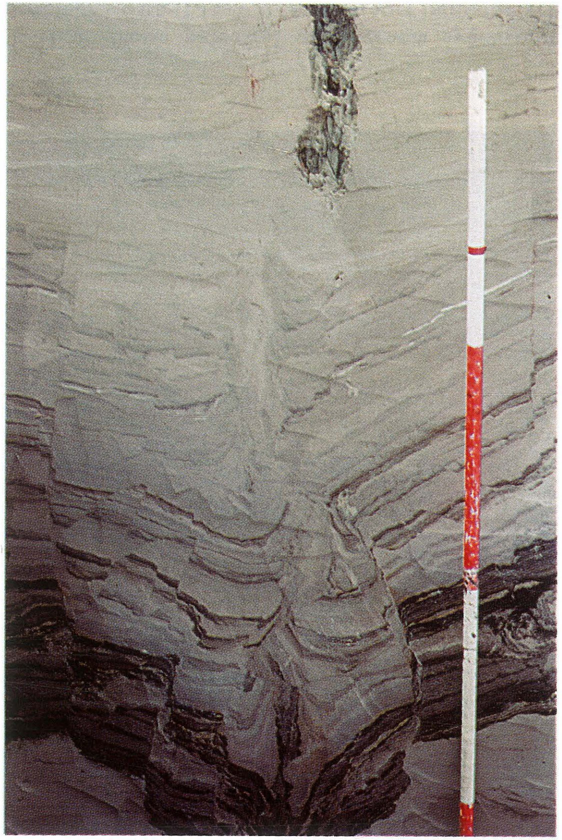


Pl. 5. Sandy and loamy channel deposits overgrown by marshy vegetation; compact peat (L15–V3) development in channel environment; Amersfoort interstadial; loamy drop soils of variable size in sand

Pl. 6. Compact peat layer (L15–V3) at short distance of the channel system; Amersfoort interstadial; distinct post genetic icewedge cast with vertical sandy infilling from L17

Pl. 7. Sandy, loamy and peaty channel deposits colmatated by peat layer (L15–V3), intensively disturbed by cryoturbations and involutions; large scale cryoturbations of the peat layer (L19–V2); small scale cryoturbations and bioturbations of the peat layer (L22–V1)

Pl. 8. Intensive cryoturbated peat layer (L15–V3)

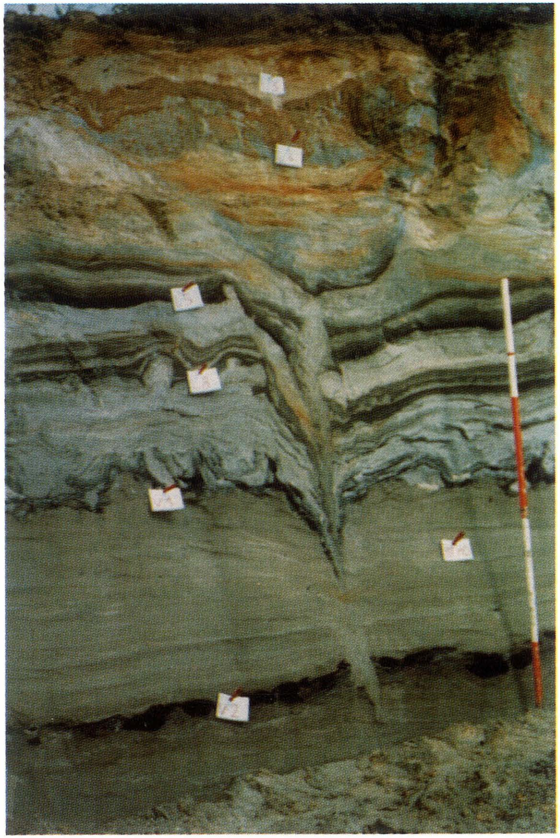


Pl. 9. Large scale ice wedge cast with blocky structure and random microfaults due to ice wedge melting; upward waterescape structures associated with ice wedge cast

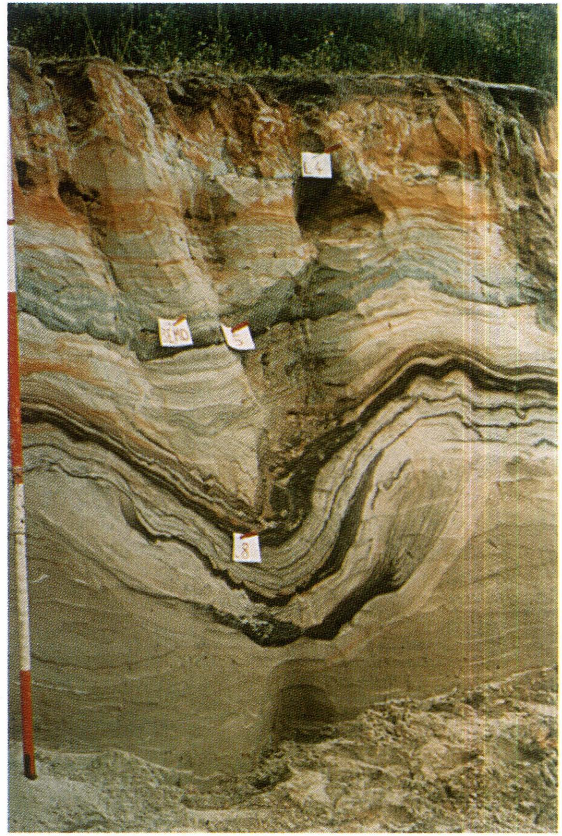
Pl. 10. Cryoturbated peat layer (L15–V3) and large scale postgenetic sandwedge with vertical parallel laminated infilling; distinct horizontal postgenetic erosion level

Pl. 11. Podzolic paleosoil of Beernem synchronic developed with (L15–V3) (Amersfoort interstadial)

Pl. 12. Level of well developed ice wedge casts with vertical infilling (3 to 4 m depth)



Pl. 13. Ice wedge cast with vertical laminated infilling and associated with lateral microtectonic structures; well developped thermokarst depression infilling at the top



Pl. 14. Thermokarst depression with sandy, loamy and peaty infilling not related with ice wedge cast