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Cryogenic Structures in the Weichselian Deposits of Northern Belgium and their Significance

By Guy De Moor*

Summary: The paper presents an inventory of periglacial structures in the Weichselian deposits of Northern Belgium, especially those of the Flemish Valley infilling. It recommends a more complete stratigraphic and sequential inventory in order to better reconstruct the Weichselian paleoenvironment and its evolution. The paper discusses cryogenic structures found in the Early-Weichselian deposits and argues for a more important impact of periglacial conditions during that period. Information is derived from the exposures in the Weichselian infill of the thalwegs of the Flemish Valley. The Early-Weichselian phenomena are placed in the framework of their morphological, climatological, sedimentological and eustatical dynamism, and a partition of the Early-Weichselian is suggested.

Zusammenfassung: Der Aufsatz behandelt das typische Inventar der fossilen periglaziären Strukturen in den weichselzeitlichen Ablagerungen Nord-Belgiens, besonders in den Ablagerungen des Flämischen Tals. Es wird die Erfassung eines vollständigen stratigraphischen und sequenziellen Inventars empfohlen, um eine bessere Rekonstruktion des weichselzeitlichen Milieus und seiner Entwicklung zu erzielen. Insbesondere wurden die fossilen periglaziären Strukturen in den frühweichselzeitlichen Ablagerungen untersucht. Daraus werden intensive Periglaziärbedingungen für diese Periode gefolgert. Die Berücksichtigung der periglaziären Erscheinungen im Rahmen der allgemeinen geomorphologischen, klimatischen und meeresspiegeleustatischen Dynamik deutet auf eine Zweiteilung der Frühweichselzeit hin.

INTRODUCTION

Northern Belgium is a lowland region consisting of an erosional landscape incised in Tertiary or Early-Pleistocene age deposits of sands and clays which dip northwards. The area includes several deeply incised misfit valleys, partly infilled by Late-Pleistocene deposits and known as the Flemish Valley and its tributaries. The sandy Weichselian infill surface of the Flemish Valley is between +5 und +15 m a.s.l., and rises slowly to the east and south. Northwards this fluvioperiglacial surface is crossed by low eolian sand ridges. It has been dissected by small Holocene river-valleys and its lowest parts are buried under intertidal deposits of the Flandrian transgression. On the interfluves, generally parts of river-cut cuestas or old Pleistocene river terraces, elevations increase southward to reach +150 m a.s.l. South of the Flemish Valley the interfluves are covered by loessic deposits.

WEICHSELIAN PERIGLACIAL DEPOSITS

In Northern Belgium the Weichselian deposits comprise:
(1) Loessic deposits of the Brabantian and South-Flemish low plateaux and hills.
(2) Fluvioperiglacial infill deposits of the Flemish Valley and its tributaries.
(3) Niveo-eolian and niveo-fluvial coversands or loams occurring as thin surficial deposits which cover the fluvioperiglacial surface of the Flemish Valley system. These include coverloams along the western side of the large SW-NE oriented Flemish Valley tributary valleys, and parts of the Pleistocene cover on the low northernmost Kempenland interfluves.
(4) Local eolian coversand ridges of Late glacial age which cross the Flemish Valley and the northern inverfluves.
(5) Periglacial slope deposits, mainly deposited by congelifluxion or laminar solifluxion.

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CRYOGENIC STRUCTURES

Several synsedimentary (i. e., not implying any interpretation of their syngenetic or epigenetic character) types of fossil cryogenic structures have been observed in the periglacial Weichselian deposits of Northern Belgium. They include:

(1) Structures indicating more or less continuous permafrost over long periods: (a) ice-wedge casts, some bearing summit nipple-like narrowing, typical of syngenetic development. (b) cryoturbation horizons indicating a rising permafrost table and, in some cases, an active layer thickness of between 0.5 and 2.0 m. (c) macro-gelifluxion structures, causing local pattern ground with sorting and vertical elements. (d) macro-diapiric structures consisting of upward injections (even of Tertiary materials) up to 2 to 3 m in height. (e) regular and chaotic diapiric structures with vertical extent usually less than 1 m. These involutions are similar to water escape structures and often restricted to peat layers. (f) frost-kettles, generally related to less permeable sediments, and having a depth up to 1 m. (g) bird-foot drop structures.

(2) Structures testifying to seasonally frozen ground or water-saturated topsoil, i. e., frost cracks, frost wedges, ball-like droptails and various forms of micro-involutions and microgelifluxion structures („Taschenboden"). The frost cracks and frost wedges are sometimes infilled with either slumped autochtonous deposits, or allochtonous waterlaid or eolian sediments.

Some loamy and peaty-loam deposits show a succession of levels with frost wedge polygonal networks. Up to 15 frost wedge levels per metre depth have been observed, especially in well-layered peaty-loam fluvioperiglacial floodplain deposits of Pleniglacial age in the Flemish Valley. Often these wedge successions are associated with large syngenetic ice-wedge casts, up to 4 m deep.

(3) Fossil thermokarst structures characterised by locally downsunken sediment layers, often associated with slide structures or water-extrusion structures.

(4) Marks of thermo-fluvial activity, such as the presence of pebbles and blocks of loose sediment interlaminated within layered channel infillings. Some blocks indicate frozen ground thickness of up to 2 metres. They occur in early-Weichselian fluvioperiglacial deposits. They are related to thawing and undercutting by running water at the foot of frozen riverbanks.

(5) The occurrence of isolated large stony blocks of allochtonous origin, laid down in fluvioperiglacial sandy or loamy sediments. They are considered to be traces of ice-rafted blocks formed by river ice following plucking from the riverbed.

STRATIGRAPHIC POSITION AND SIGNIFICANCE OF CRYOGENIC STRUCTURES

In addition to the Netherlands (VAN DER HAMMEN, MAARLEVELD, VOGEL & ZAGWIJN, 1967) and Germany (ROHDENBURG, 1967), litho- and chronostratigraphic schemes have been developed to show the stratigraphical position of certain cryogenic structures in the Weichselian deposits of Northern Belgium (PAEPE & VANHOORNE, 1967). They allow stratigraphic and paleo-environmental interpretations.

Synthesis of the stratigraphic occurrence of those cryogenic structures diagnostic for frozen ground (permafrost) has been made by KARTE (1981).

The use of these schemes however, is hindered by uncertainty about the meaning of the cryogenic features. It is not clear whether they indicate levels of isomorphic cryogenic structures or separate cryoturbation levels. In the case of the latter they may show the real frequency of periglacial features and conditions in the successive stratigraphic units. Many recent observations show that the frequency of levels with frost wedge casts and cryoturbation structures in the Weichselian Pleniglacial deposits of Northern Belgium have been underestimated. Most Belgian and Dutch schemes hardly mention anything more than a few levels with frost wedge casts and cryoturbation structures during the pre-Denekamp Pleniglacial.

The periglacial environment of the last ice age in Northern Belgium experienced an unstable climate character unless one assumes a greater impact of local conditions upon the development of cryogenic structures. All the stratigraphic schemes show little information about cryogenic structures of pre-Amersfoort Early-Weichselian age. Even for the younger pre-Moershoofd part of the Weichselian they show only one single level of ice-wedge casts and a few levels with cryoturbation structures or frost wedge casts.

From these data, should one conclude that the Early-Weichselian in Northern Belgium experienced only weak periglacial conditions, as suggested by paleobotanical data (DE GROOTE, 1977)? Alternatively, is there a lack of stratigraphic and sedimentological data for that period, especially concerning cryogenic structures?

PERIGLACIAL PHENOMENA DURING THE EARLY-WEICHSELIAN IN NORTHERN BELGIUM

Two exposures of Early-Weichselian deposits in the infill of the Flemish Valley thalweg system allow one to assess the periglacial dynamism of the Early Weichselian in Northern Belgium.

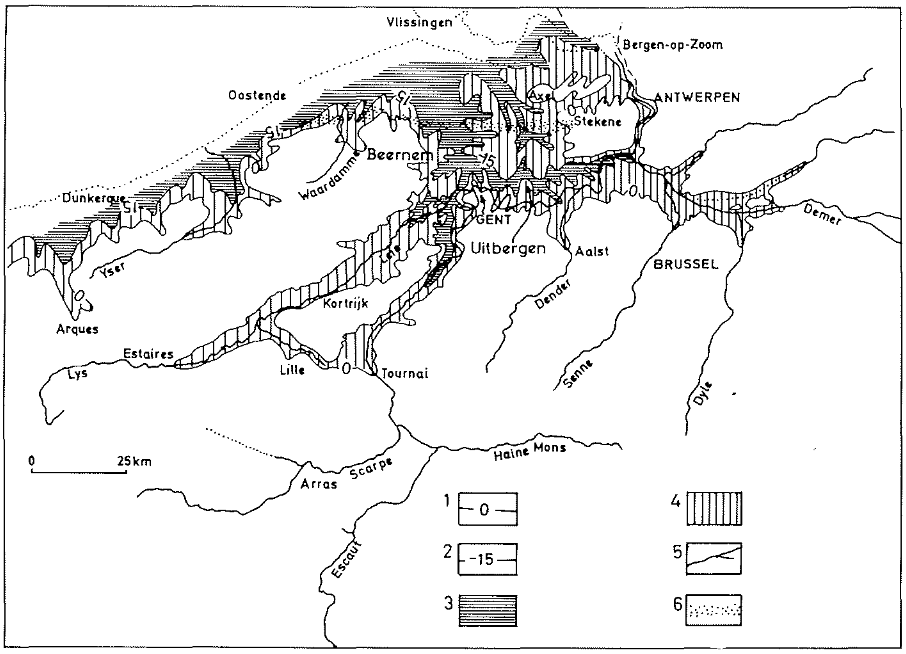

Fig. 1: Extension of the Flemish Valley and its main tributaries. Surface of the base of the Quaternary infilling: 1 = 0 m a.s.l. contourline, 2 = —15 m a.s.l. contourline, 3 = area below —15 m, 4 = area between 0 and —15 m. Present-day surface: 5 = main river, 6 = main coversand ridge.

Abb. 1: Das Flämische Tal und seine Hauptnebenflüsse. Basisoberfläche der Anfüllungsschichten: 1 = 0 m NN Isohypse, 2 = —15 m NN Isohypse, 3 = Zone unter —15 m, 4 = Zone zwischen 0 und —15 m. Aktuelle Oberfläche: 5 = Hauptfluß, 6 = Hauptdecksandrücken.

The first exposure is situated at Uitbergen (see Fig. 1) in one of the deeply scoured main thalwegs of the Flemish Valley and near to its southern edge. Here, impact of the post-Eemian sea level fall upon the fluviatile system has been intense and quick. Sandy and peaty-loamy Eemian deposits of fluviatile and intertidal origin have been scoured over several metres before being buried under Weichselian deposits.

The second exposure is situated at Beernem (see Fig. 1) in a small tributary valley of the Flemish Valley system. Here, due to distance and because of geological reasons (resistant substratum of Tertiary age sand with sandstone layers and the occurrence of a belt of clayey Eemian deposits at the mouth of the tributary valley) the influence of the post-Eemian sea level fall upon the fluviatile system has been weak.

At Uitbergen the sequence shows (Fig. 2) a major erosional hiatus between the Eemian remnants and the lowest part of the Weichselian deposits. The lowest Weichselian deposits in the exposure consist of coarse fan deposits (Eo-Weichselian B, formation of Dendermonde) containing evidence of cold conditions, such as ice-wedge casts, macro-gelifluxion structures and traces of fluvio-thermal acitivity. In addition, they contain skeletons of large mammalia infected by fossil *Protophormia Terraenovis* (GAUTHIER, 1974), and traces of ice rafted blocks of Paleozoic rocks which outcrop in the Pleistocene thalwegs of some southern tributary rivers.

The Early-Weichselian age of the deposit (which becomes finer in a distal direction) is given by its posi-

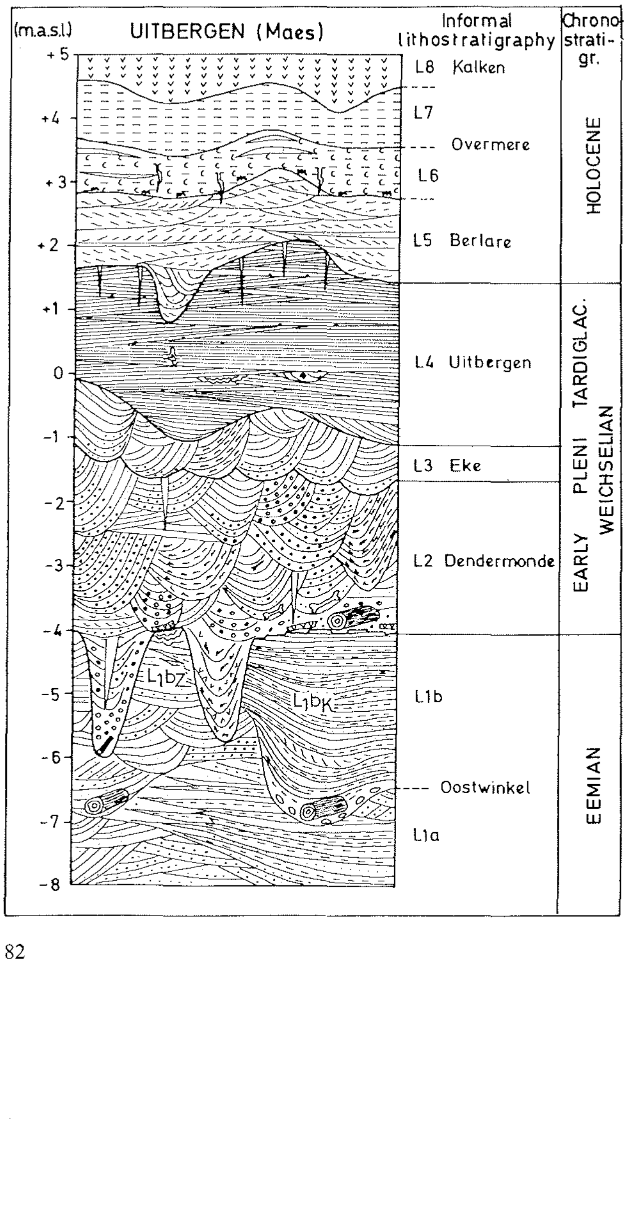

Fig. 2: The Early-Weichselian sequence at the Uitbergen outcrop.

Abb. 2: Frühweichselzeitliche Abfolge im Aufschluß bei Uitbergen.

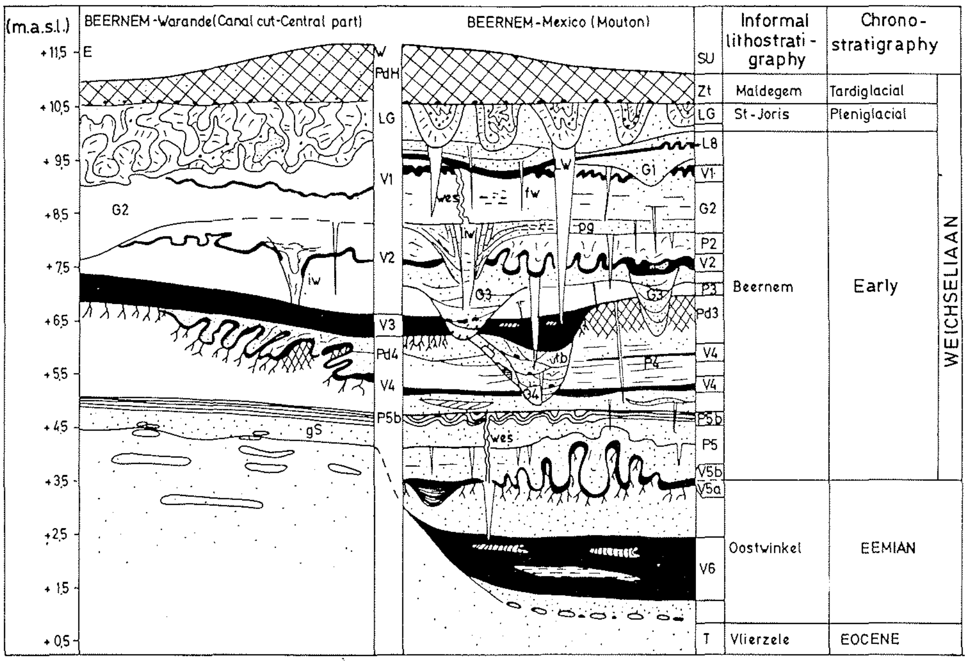

Fig. 3: The Early-Weichselian sequence at the Beernem outcrop.

Abb. 3: Frühweichselzeitliche Abfolge im Aufschluß bei Beernem.

tion in the Weichselian lithostratigraphic sequence for the Flemish Valley. The occurrence of large slabs of Eemian or Early-Weichselian peat, of whole thermophyle tree stems and of reworked Eemian *Corbicula fluminalis* fossils support that interpretation. Deposition itself followed an initial Early-Weichselian phase characterised by deep incision due to reactivation of fluviatile erosion following the sea level fall (Eo-Weichselian A).

The exposure at Beernem (Fig. 3) shows a more or less continuous sequence from the Eemian (Eemian peats from pollenzones E4, E5 and E6 according to DE GROOTE, 1977) to Eo-Weichselian deposits. The lowermost, pre-Amersfoort part contains relatively tree-rich pollen spectra. The younger post-Amersfoort part contains only thin peat layers with rather tree-poor pollen spectra (DE GROOTE, 1977). The whole local Eo-Weichselian sequence shows 6 peat horizons.

The Eo-Weichselian age of the sequence is given by the following evidence. The uppermost peatlayer (L8) of the sequence shows a radiocarbon age of more than 50,300 years B.P. ($\pm$3,800 years) (Gr-7241). According to the chronostratigraphy of ZAGWIJN & PAEPE (1968) the whole sequence is older than the beginning of the Middle-Weichselian (55,000 years B.P.). The minimal age of the peat is not contrary to more recent opinions suggesting a 70,000 years B.P. radiocarbon age for the earliest Middle-Weichselian (WOILLARD & MOOK, 1982). The Early-Weichselian age is also confirmed by the cryogenic structures situated at the top of the sequence, consisting of a level of large ice-wedge casts developed in a sandy layer and originating from the base of an horizon of large frostkettles and diapiric structures developed in layered loamy material containing laminae of coarse sand and fine gravel. The cryogenic complex indicates a first cold maximum, as accepted for the earliest Meso-Weichselian.

The local Eo-Weichselian sequence comprises an alternating succession of peaty layers alternating with sandy valley bottom sediments, floodplain and braided channel sediments, and wash sediments (DE

MOOR, 1981). Two phases of more important fluviatile scouring occurred under rather cold conditions before and after the Amersfoort interstadial. The Amersfoort age of the V3-peat layer (Fig. 3) is based on paleobotanic evidence (DE GROOTE, 1977). Moreover, the peat is associated with a well developed podzol soil situated on higher ground in the buried microrelief and showing a diagnostic similarity to the Amersfoort morphotype (MAARLEVELD, oral communication, 1977).

This whole Eo-Weichselian sequence shows numerous levels of distinct cryogenic structures. Many levels indicate the former existence of frozen ground. Several phases of permafrost conditions are suggested by ice-wedge casts. A schematic profile of the Eo-Weichselian sequence and a scheme of the stratigraphic succession and types of cryogenic structures diagnostic for frozen ground and permafrost are given in Fig. 4.

CONCLUSIONS

(1) Comparison of both exposures shows the importance of their morphological situations upon the evolution and genesis of the sediments and their impact upon periglacial phenomena.

(2) During the Early-Weichselian periglacial processes had already been important in Northern Belgium. Frozen ground phenomena had developed earlier in the Eo-Weichselian A, although the recorded paleobotanical conditions do not yet indicate advanced vegetation deterioration. Periglaciation was much more advanced during the post-Amersfoort Eo-Weichselian B as proven by the intensity and frequency of frozen ground traces and the frequency of levels with permafrost indicators.

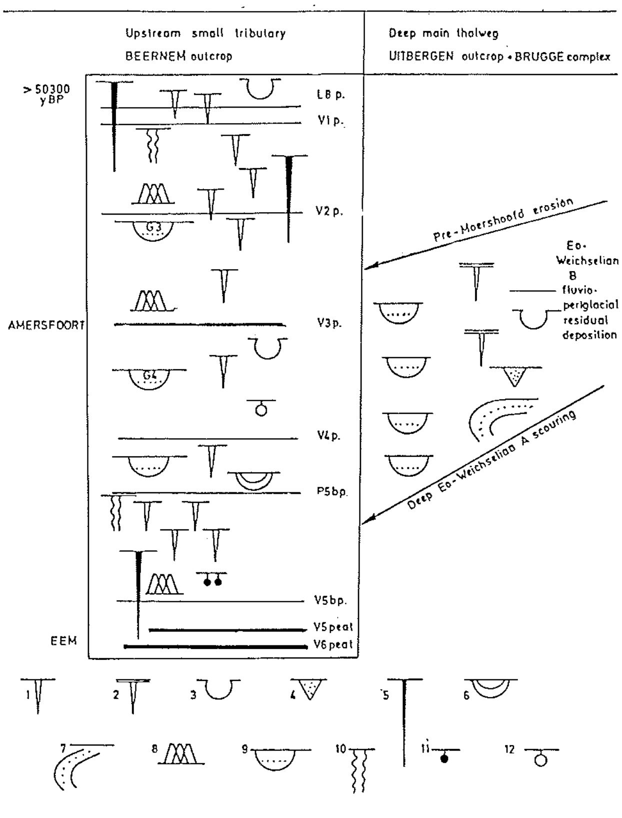

Fig. 4: The sequence and type of cryogenic structures in the Eo-Weichselian infilling of the Flemish Valley thalwegs in Northern Belgium.
1 = frost wedge, 2 = eroded frost wedge, 3 = frostkettle, 4 = sandwedge, 5 = ice wedge, 6 = involution, 7 = macrocongelifluxion, 8 = mollisoldiapirism, 9 = fluviothermal acitivity, 10 = water escape structure, 11 = droptail (Wieme type), 12 = droptail.

Abb. 4: Abfolge und Typen fossiler periglaziärer Strukturen in frühweichselzeitlichen Talsanden des Flämischen Tales in Nord-Belgien.
1 = Frostkeil, 2 = erodierter Frostkeil, 3 = Frostkessel, 4 = Sandkeil, 5 = Eiskeil, 6 = Involution, 7 = Makrogelifluktion, 8 = Mollisoldiapirismus, 9 = fluviothermale Aktivität, 10 = Wasserentweichstruktur, 11 = Tropfenboden (Wieme-Typ), 12 = Tropfenboden.

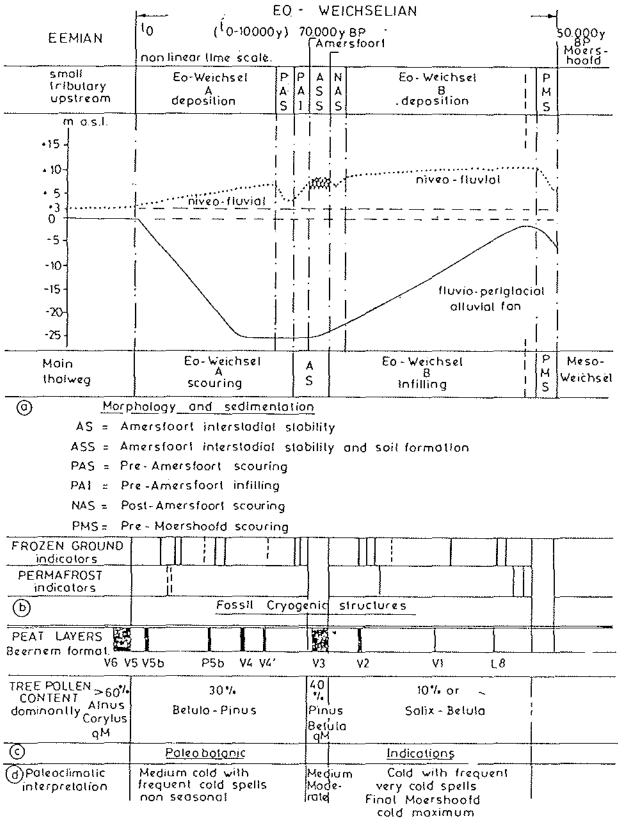

Fig. 5: The Eo-Weichselian environment and its dynamism in the Flemish Valley and its tributaries in Northern Belgium.

Abb. 5: Frühweichselzeitliches Milieu und seine Dynamik im Flämischen Tal und seinen Nebenflüssen in Nord-Belgien.

(3) In the main axes of the Flemish Valley thalweg system, the eo-Weichslian A corresponds mainly to a phase of deep and fast fluviatile erosion and downcutting. If one considers the velocity of the anaglacial sea level fall comparable to that of the cataglacial sea level rise (JELGERSMA, 1979), the majority of the sea level fall may have occurred within a time span of 10,000 years. In some of the smaller tributary valleys the fluviatile response to the sea level fall during the Eo-Weichselian was limited. There, one finds sediments associated with the paleo-environmental conditions during the pre-Amersfoort Eo-Weichselian A. Nevertheless, the Beernem exposure suggests that the end of the eo-Weichselian A corresponded to an upstream shifting of the neutral point in the river length profile.

(4) Contrary to eustatic impact, the morphological and sedimentological effects of the climatic deterioration became perceptible after the Amersfoort interstadial. Due to the climatic deterioration, the vegetation cover and the soils of the interfluves were eroded while development of frozen ground and active layer increased gelifluxion. River discharge also increased together with the solid load, forcing braiding of the fluvioperiglacial river runoff and deposition in the thalweg system of the Eo-Weichselian B. Fig. 5 shows a model of the long term morphological, sedimentological, climatological and eustatic dynamism during the Early-Weichselian in Northern Belgium.

(5) More information is required of the stratigraphical inventory of periglacial features in order to obtain a better knowledge of the Weichselian paleo-environment and its evolution. Moreover, more attention should be paid to the types and frequencies of occurrence of cryogenic structures in relation to different lithological, sedimentological and other conditions.

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