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A multi-diciplinarypalaeoenvironmental survey in the western *Moervaart*-depression (East Flanders, B)

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Summary

In light of a nature restoration project, a multi-disciplinary survey was conducted in the western part of the '*Moervaart*-depression', a Late Glacial palaeolake. This survey, consisting of a geophysical and an augering survey, and palaeo-ecological analysis, aimed at the development of a general palaeo-environmental framework of the study area. The results show a complex geomorphological and sedimentary evolution of the area, with several fossil channels and a palaeo-ecological record from the early Late Glacial period to the Late Holocene.

Keywords: '*Moervaart*-depression', Ghent, prov. Oost-Vlaanderen (B), palaeo-environmental survey, fluvial dynamics, Late Glacial period.

1. Introduction

In compensation for the expansion of the Ghent Harbour, several areas suitable for the creation of wetlands are evaluated. Two of these are situated in the western part of the *Moervaart*-depression (Flanders, Belgium). A first zone, *Moervaart-Noord* situated near Sint-Kruis-Winkel, is a low-lying area situated between the slope of the coversand-ridge Maldegem-Stekene in the north and the Moervaart channel in the south. A second zone lies more to the south and is bordered by the Moervaartchannel in the north and by the Zuidlede river in the south (Fig. 1, 2).

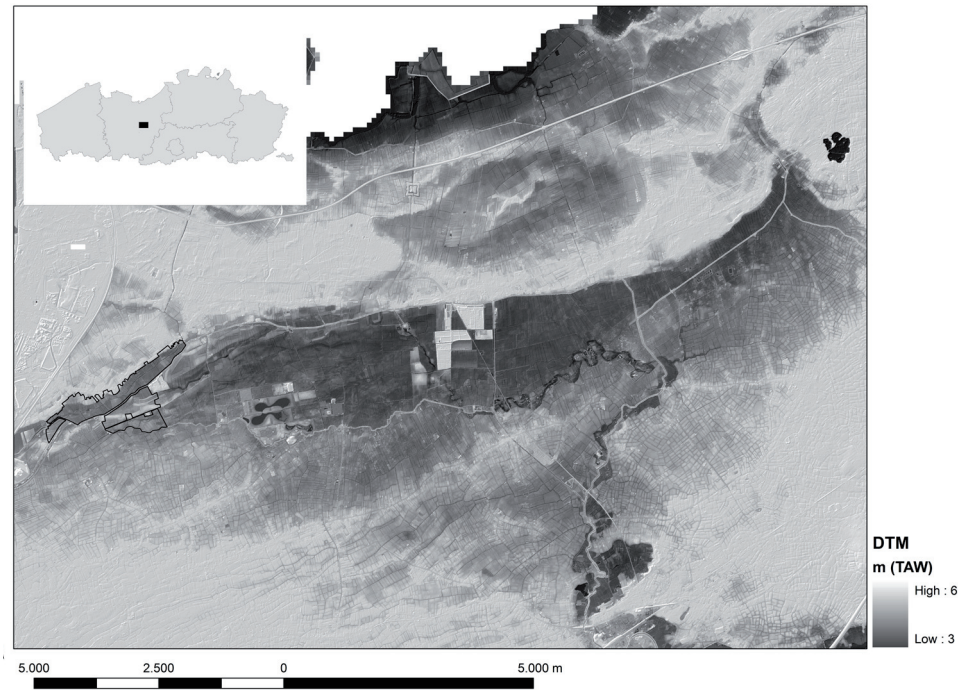

Fig. 1 - DTM of the *Moervaart*-depression with indication of the study areas.

Because of the geological and archaeological richness of the *Moervaart*-depression and the cultural-historical value of this area, a project was set up in cooperation between the Nature and Forestry Agency (ANB) and the Flemish Heritage Institute (VIOE). The aim of this project was to evaluate the consequences of the

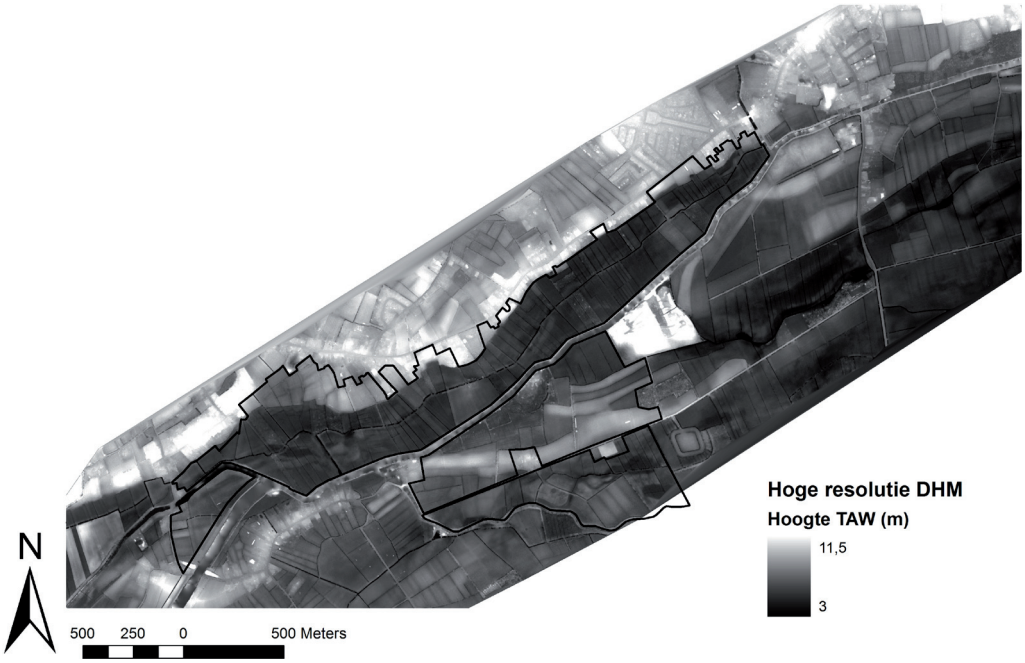

Fig. 2 - High resolution DTM of the study areas.

envisaged developments for the present heritage values. As a part of this project a multi-disciplinary survey was conducted, with emphasis on the *Moervaart-Noord* area, consisting of a geophysical survey (conducted by Ghent university), an augering survey, and palaeo-ecological analysis of a selection of sediments. None of these aspects was conducted at a high resolution, as only a general sedimentary and geomorphological framework was envisaged. This article discusses the methodology and results of this survey.

2. *Geophysical survey* (De Smedt *et al.*, 2011)

The geophysical survey was conducted using a multi-receiver electromagnetic induction (EMI) instrument. This way, the soil apparent electrical conductivity (ECa) was measured, which allowed mapping the pedological variability of four different soil volumes. A more detailed description of this methodology and a discussion of its potential in detecting

Fig 3 – Overview of the ECa measurements (soil volume 0-1.5 m below the surface) of the four surveyed zones (1-4). High ECa value indicate a higher clay content and/or a higher organic matter content, the low ECa values represent sandy areas. The dashed white line traces the present-day Moervaart river.

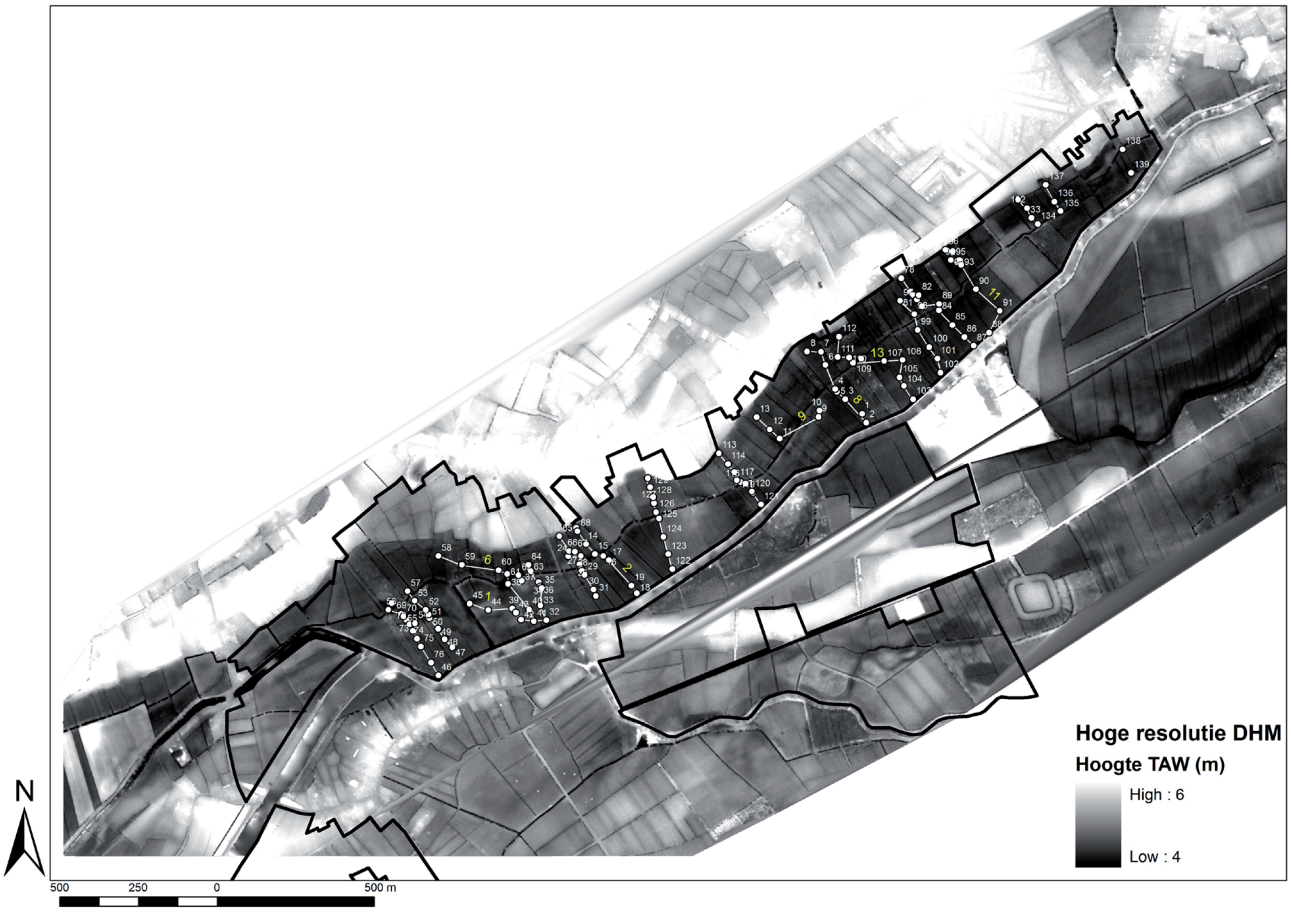

Fig. 4 – Localisation of all the augering points and described cross-sections in the *Moervaart-Noord* area.

palaeogullies and other geomorphological features can be found in Bats *et al*., 2009 and De Smedt *et al*., 2011. Within the boundaries of the project it was not possible to survey the entire study area. Instead, four zones of a total of 30 ha were selected for detailed EMI survey; three zones in the 'Moervaart-Noord' area and one parcel in the southern 'Moervaart-Zuidlede'-area (Fig. 3: 1-4).

The results (Fig. 3) show thin clayey deposits in the northern part of the study area (1), together with small gullies or depressions filled with organic to clayey sediments. In the western part (2), the survey indicated the presence of at least one larger palaeogully and a number of smaller gullies. Furthermore, a number of small sandy ridges and small depressions were detected. In the more homogeneous central zone (3), a possible palaeogully was detected close to the present-day Moervaart channel. In the southern zone (4) a similar feature can be seen close to a contemporary ditch in the north of this zone.

3. The augering survey

The augering survey was conducted using both gauge (Ø 3 cm) and spiral (Ø 5 cm) augers. Every boring was described in the field according to dominant texture (sand, clay, silt...), secondary textures (clayey, sandy...), other main components (peat, gyttja...), colour, presence of minerals (vivianite, glauconite,...), etc. The augerings were mapped using a GPS with a horizontal precision of ca. 2 m. Z-values of the top of the augerings were derived from the high resolution DTM (Fig. 4).

For the sedimentary analysis and the drawing and description of cross sections (Fig. 5) of the area a set of lithofacies was defined. These lithofacies were subsequently interpreted towards general architectural elements (Tab. 1, Tab. 2).

The augering results confirm and clarify the geophysical survey results. Especially in the western part of the study area a number of relatively broad and deep fossil channels is present. Next to this several smaller channels were recognized throughout the whole *Moervaart-Noord* area.

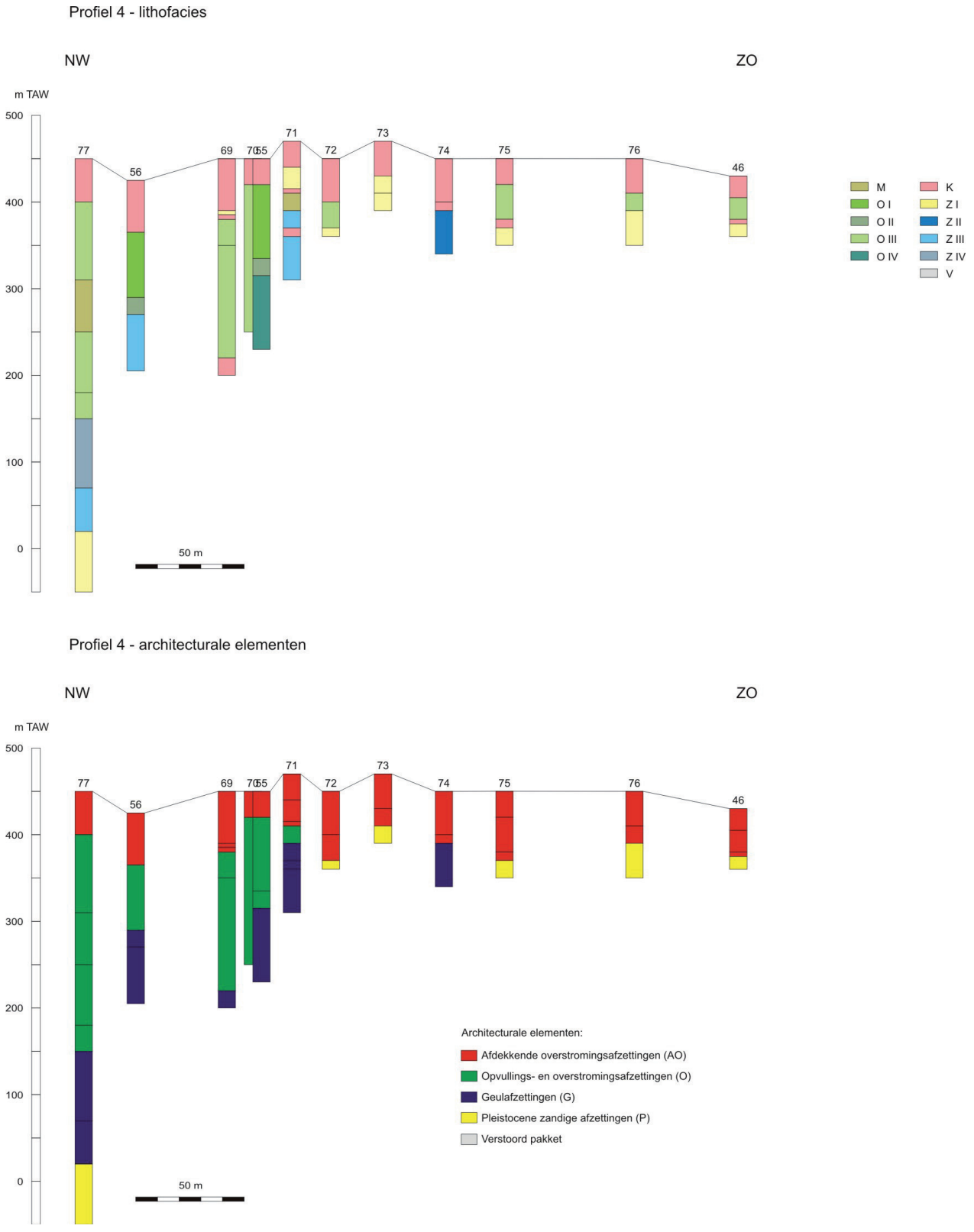

Fig. 5 - Example of a cross section, based on the recognized architectural elements and with indication of the defined lithofacies.

Lithofacies	*Maincharacteristics*	*Secondarycharacteristics*
Organic facies (O)		Mollusk fragments
OI	Peat	
OII	Gyttja	Calcareous deposits
OIII	Organic to peaty clay	
OIV	Very organic sand	
Calcareoustufa facies (M)	Calcareous tufa	
Fine clastic facies (K)	Clay- silt	Mollusk fragments, oxidation spots, sometimes with a sandy admixture
Sandy facies (Z)		
ZI	Fine/ half-fine sand	Organic spots and vegetation remains in the top part, glauconite
ZII	Fine/ half-fine sand	Clayey admixture, vivianite, mollusk fragments
ZIII	Fine/ half-fine sand	Clayey and/or organic laminae(<1 cm) or layers, mollusk fragments, vegetation remains
ZIV	Fine to medium sand	Large number of mollusk fragments

Tab. 1 - General overview of the defined lithofacies.

Architectural element	*Interpretation*	*Associated lithofacies*
Pleistocene sandydeposits(P)	All Pleistocene sandy deposits at the base of augering sequences	ZI
Fluvialdeposits (G)	All sediments deposited in a dynamic fluvial environments (channel deposits, crevasse deposits; with the exception of these included under 'P')	OIV, ZII, ZIII, ZIV
Aggradation and floodplain deposits (O)	Sediments formed or deposited in channels or floodplains under a low dynamic fluvial environment	OI, OII, OIII, M, K
Covering floodplain deposits (AO)	Mostly the top element in the study area	K

Tab. 2 - Overview of the architectural elements.

The infilling of these gullies shows a wide variety of sediments, from organic rich sandy sediments, to gyttja and peat, to half- fine and medium sands. Outside the fossil channels the underlying Pleistocene sands shows a softly undulating topography, in which several small ridges can be recognized. These higher parts of the palaeotopography are in some parts not covered by later fluvial or alluvial sediments. The lower parts are mostly covered by a thin layer (20 cm to ca. 1 m) of sandy clay. In the eastern part of the *Moervaart-Noord* area almost no deposits characteristic for dynamic fluvial activity were encountered, although a clear pattern of long and narrow depressions is visible there. These depressions are mostly filled with very organic clay, indicating that they aggraded as a part of the floodplain.

4. Palaeo-ecological research

Because of the wide variety of morphological structures several sequences were sampled and analyzed on a general level, instead of studying one sequence in detail. Primary purpose was indeed to assess the main palaeoecological characteristiscs, preservation, scientific potential and heritage value. Based on the above described geomorphological and sedimentary framework, five sequences were selected in the western part of the *Moervaart-Noord* area (Fig. 6). These sequences comprise the infillings of five depressions, with differing combinations in morphology, depth, and lithological characteristics (Fig. 7).

Fig. 6 - Locations of the sampled sequences.

The sampling was carried out with a Ø 3 cm gauge auger. Subsamples of ca 1 cm³ were taken and prepared for pollen analysis. Subsamples of ca 10 cm in length were taken from just under each pollen sample for the analysis of plant macrofossils (Fig. 7).

To gain insight in the start of the aggradation within the sampled depressions/fossil channels, five bulk samples (*ca* 1 ml) for radiocarbon dating were selected from the base of the sequences. The AMS dating was done at *Beta Analytic* (Florida, USA). The results are presented in table 3. These demonstrate that at similar depths deposits of totally different ages occur.

4.1. Pollen analysis

Based on the pollen data and radiocarbon dating a general evolution of the vegetation and sedimentary developments can be described.

Sequence	*Depth*	*Lab. code*	*Conventional age (^{14}C years BP)*	*Calibrated age (2 σ, Cal BP)*
MVN11-A	332 cm	Beta-302747	11220 +/- 50	13210 – 13050
MVN11-B	509 cm	Beta-302749	10790 +/- 50	12860 – 12790
MVN11-B	285 cm	Beta-302748	2150 +/- 40	2310 – 2230; 2200 – 2010
MVN11-C	191 cm	Beta-302750	12450 +/- 50	14800 – 14200
MVN11-E	250 cm	Beta-302751	11110 +/- 50	13110 – 12920

Tab. 3 - Results of the radiocarbon dating.

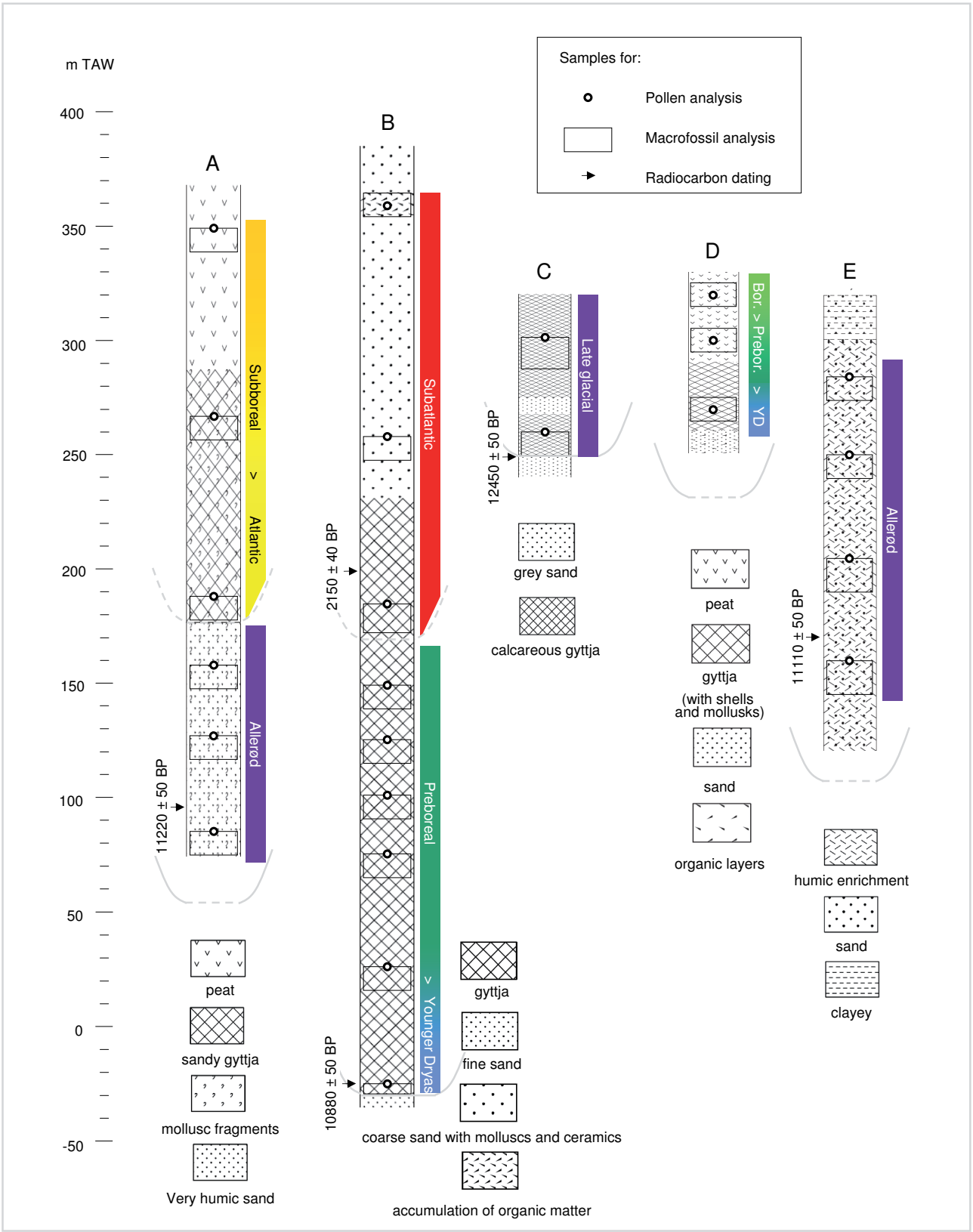

Fig. 7 - Sampled sequences at absolute depths (m TAW) with indication of lithology, subsamples for pollen and plant macrofossil analysis, radiocarbon dating results and supposed chronological periods.

- *Start of the Late Glacial period (Oldest Dryas / Bølling)*: from this period a shallow and narrow gully is recognized, filled with calcareous gyttja (MVN11-C). The pollen analysis shows a very open landscape.

- *Allerød*: A wider and deeper channel (incised to a depth of at least ca + 1 m TAW, the base of the channel fill was not reached) was filled with organic rich sandy deposits during the Allerød period (MVN11A & E, probably belonging to the same channel), in a fairly open landscape with patches of pine and birch forest. The sedimentary characteristics (sandy texture) and the presence of reworked pollen demonstrate a dynamic fluvial environment.

- *Younger Dryas and Early Holo-cene*: Sequences MVN11-B en -D both show an infilling with gyttja; starting in the Younger Dryas period, within an open almost treeless landscape. Yet both these sequences belong to different channel systems. Sequence MVN11-B was taken in a deep channel (to -0.3 m TAW), while sequence MVN11-D is situated in a shallow depression. Neither of these sequences aggraded within a dynamic fluvial regime. During the Preboreal and Boreal periods this low dynamic regime continued, with accumulation sediments mainly comprising organic deposits. The vegetation developed to a forested environment, at first mainly with birch, followed by a dominance of pine and the advent of hazel.

- *Late Holocene*: During the course of the Holocene several fluvial reactivations took place in the study area. This is shown both in MVN11-A and MVN11-B by chronological hiatuses in the sequences, which are interpreted as new incisions in these channels eroding the older deposits. The infilling of these newly incised channels in both cases starts with gyttja, demonstrating initial aggradation in a calm fluvial regime, possibly indicating that these eroding phases were short lived events. In MVN11A this aggradation (gyttja followed by peat) already started in the Atlantic or Subboreal periods, with the pollen analysis indicating the dominant presence of alder within the arboreal pollen. The incision and initial aggradation in the MVN11-B sequence occurred in the Iron Age Subatlantic period. This was followed by a period with a very active fluvial regime, depositing coarse sands, plant remains, a large number of mollusk fragments, and ceramic fragments. The pollen analysis shows a clear human influence on the vegetation (deforestation, cereals,...).

4.2. Plant macrofossils

Whereas the palynological record shows clear differences over the studied sequences, that is not the case for the macrofossil record. This is most probably due to the fact that the macrofossil record only reflects the local stand (in contrast with a combined local and regional palynological view) and the fact that, in spite of the different ages of the sampled sequences, the local vegetation developed in the same way. The general image is one of, in succession or contemporary, often the same water plants, riparian species and species of drier, more nutrient rich and disturbed places. As trees and/or shrubs birch species have been recorded, including dwarf birch (*Betula nana*). In terms of actual phytosociology the attested spectrum of species could tentatively be interpreted as species belonging to what would nowadays be the Potametea (water plants in open, fresh and nutrient rich water), the Phragmitetea (vegetation types on nutrient rich, mostly permanently wet places along banks and in marshes) and the Bidenteteatripartitae (pioneering vegetation types at nutrient rich places, that are submerged in winter and emerge in summer).

5. Synthesis

The combination of augering and geophysical survey, high resolution DTM and palaeo-ecological analysisallow (in part) to develop a general sedimentary and geomorphological framework for the study area.

In the western part of the *Moervaart-Noord* area a relatively broad and deep fossil channel is present, to the south flanked by a sequence of narrow linear ridges and depressions, probably originating from a scroll bar system associated with this channel. Also in the easternmost part of the area a series of linear depressions and ridges is present, which might reflect the presence of scroll bars.

The aggradation of the wider and deeper channels in the Moervaart-Noord area started in the Allerødor YoungerDryas periods, which seems analogous with similar channels present in the central *Moervaart* depression (Bats *et al*., 2009, 2010). The aggradation of these channels continued until the Boreal period.

Beside these larger channels several smaller gullies were encountered and partly mapped, spread throughout the whole *Moervaart-Noord* area. Pollen analysis and radiocarbon dating on one of these channels show aggradation of this channel from the beginning of the Late Glacial period. Again this parallels a system of similar gullies in the central Moervaart-depression (Bats *et al*., 2009, 2010).

Striking is the occurrence of several reactivation events within the larger gullies in the Late Holocene. In sequence MVN11-A this incision is marked by a new sequence of aggradation from the Atlantic or Subboreal period onwards. In sequence MVN11-B the renewed fluvial incision seems to be of a younger date, since the infilling starts in the course of the Iron age. The sediments of this fill (coarse sand, ceramic fragments,...) indicate a very dynamic fluvial regime.

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