14,700 years of climate and environmental change recorded in 17.8 meters of lake and peat deposits in the Nieuwe Veen pingo remnant near Hardenberg, NE Netherlands

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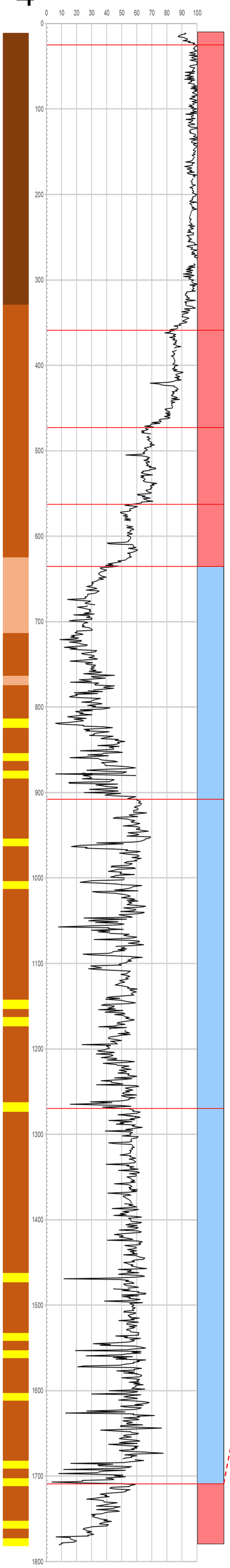

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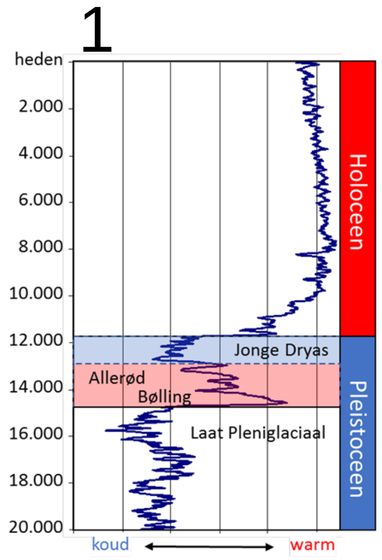

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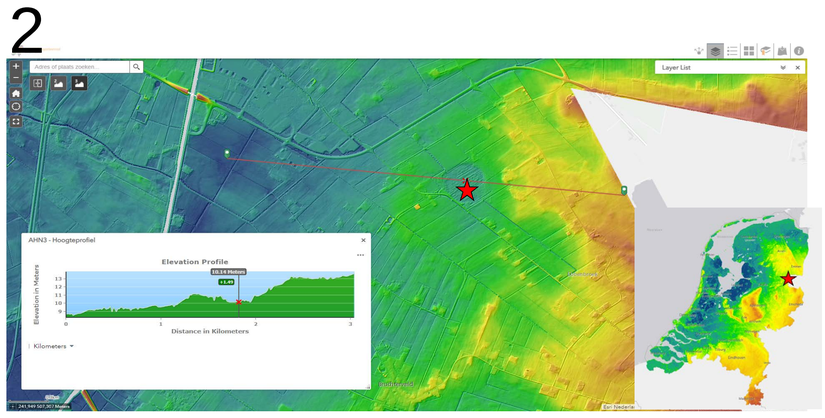

Fig 1: Temperature development over the last 20,000 years after NGRIP oxygen isotope record.
Fig 2: Location and morphology of the Nieuwe Veen near Hardenberg, core location: ★
Fig 3: Development of a pingo into a pingo remnant from the Late Pleniglacial onward.
Fig 4: Loss-on-Ignition record of the 1780 cm core, with lithological column left, and right the warm Bølling- Allerød interstadial and Holocene (red) vs cold Younger Dryas (blue).

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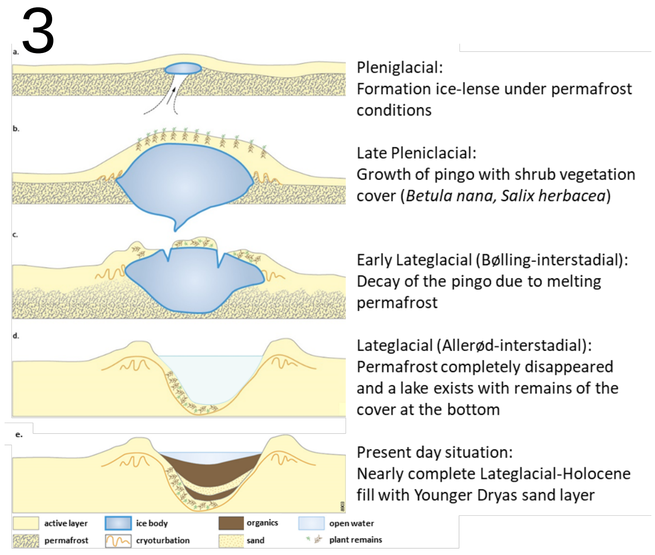

INTRODUCTION

Pingo remnants that formed during the end of the Weichselian (Late Pleniglacial, **1**) due to permafrost degradation are abundant in the northern Netherlands. Most of these circular depressions are filled with 5-10 meters thick lake and peat deposits and form a valuable archive of climate and environmental change (**3**). These natural sediment- and pollen-traps record the rapid changes during the last Glacial-Interglacial transition and reveal the Holocene forest development with traces of (early) human impact in the surrounding landscape. In this study we report on the continuous fill of the deepest pingo remnant known so far, from Nieuwe Veen near Hardenberg close to the NL-D border (**2**).

RESULTS

The fill contains almost **18** meters of organic deposits (**4**) and is composed of a sequence of lake (*light brown*) to peat (*dark brown*) deposits containing fine (algal) and coarse detrital gyttjas, calcium- and iron-carbonate gyttjas (*pink*) indicating carbonate rich seepage (**5**) and Holocene sedge, wood and moss peats with abundant macrofossils (see some of the pictures below).
The results from detailed palynological analyses on a 5-10 cm resolution reveal both regional and local aquatic vegetation development (**6**). A series of radiocarbon dates on selected terrestrial macrofossils (**6,8**) provides a solid age-model for the complete sequence starting at 14,700 calendar years ago, coinciding with the first warming of the Bølling-Allerød Interstadial (**7,8**) with an abrupt change at 1708 cm (**9**) at the onset of the Younger Dryas.
Loss-on-ignition (LOI) measurements at 1-cm resolution (**4**) support the palynological indications for openness of the vegetation cover and sandy layers (*yellow*) during colder periods as well as, remarkably variable, phases of human forest clearance (top **6**).

DISCUSSION

A period of particular interest is the cold Younger Dryas stadial which is represented by a **10 meters** thick layer of sandy gyttjas, allowing for an unprecedented detailed record on a resolution of potentially **1 cm/yr**.

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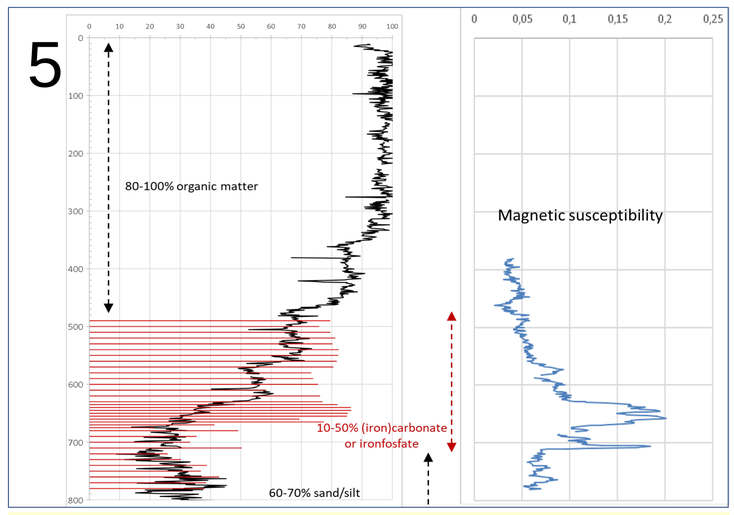

Fig 5: LOI of the top 8 meters core. Between 5-7 meters carbonate is present, consisting of iron-carbonate between 6.3 and 7 meters, with high magnetic susceptibility values at the onset of the Holocene.

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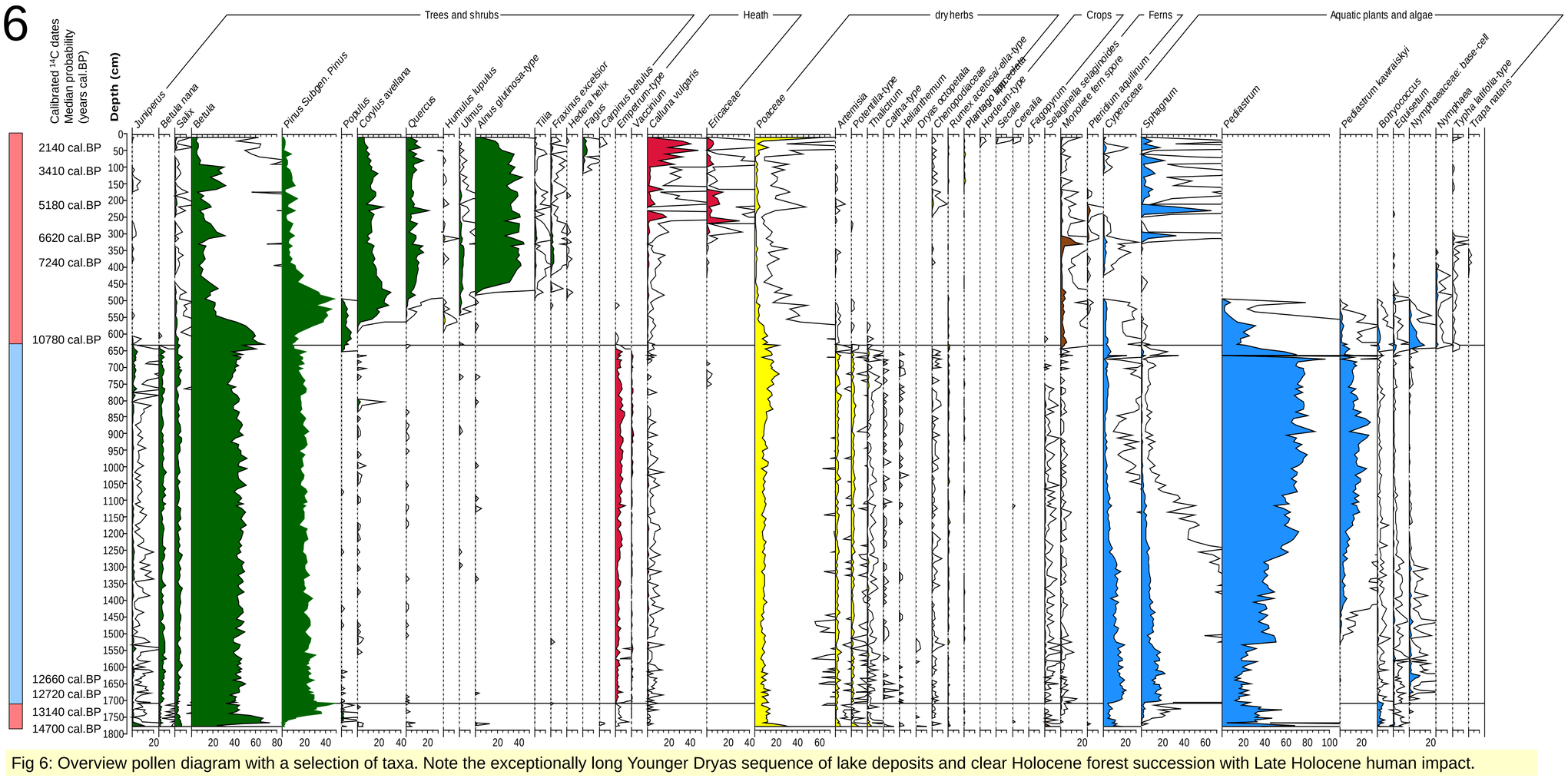

Fig 6: Overview pollen diagram with a selection of taxa. Note the exceptionally long Younger Dryas sequence of lake deposits and clear Holocene forest succession with Late Holocene human impact.

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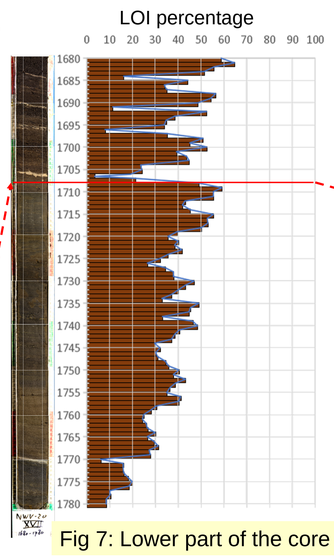

Fig 7: Lower part of the core 16.8-17.8 m, with cm LOI values

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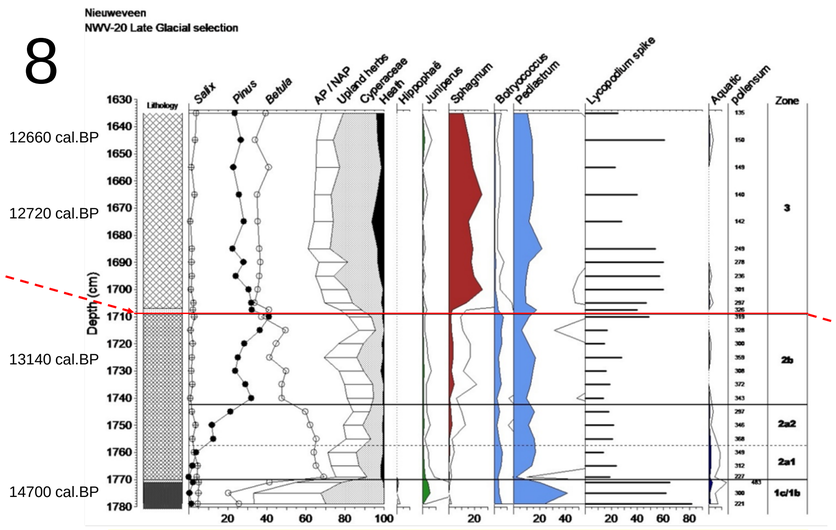

Fig 8: Basal pollen diagram with the Allerød - Younger Drays transition

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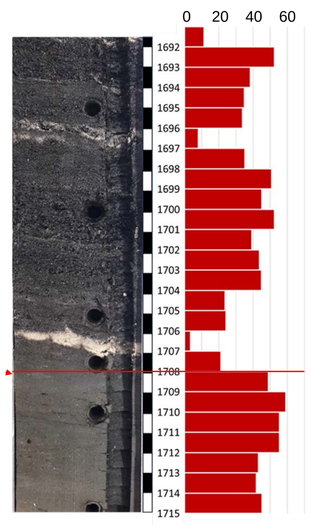

Fig 9: Detail of the transition with drop in LOI and shift from fine-coarse detrital gyttja with sand layers