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Abrupt climate change and direct vegetation development during the Last Glacial-Interglacial Transition

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Introduction

The Last Glacial-Interglacial Transition (LGIT) is one of the most intensively studied periods in Earth History. The LGIT is classically sub-divided into a series of cold stadials such as the Younger Dryas Stadial (named after the occurrence of the characteristic arctic-alpine plant species *Dryas octopetala)* separated by warm interstadials named after the type localities Bølling and Allerød in Denmark. In The Netherlands, hundreds of pollen diagrams are depicting the Lateglacial vegetation development (eg. Figure 1). While vegetation development during the LGIT is generally supposed to lag behind the abrupt climate changes as recorded in the Greenland ice core records, there is a clear temporal pattern in vegetation changes over the LGIT. How are these vegetational changes related to the abrupt changes in climate?

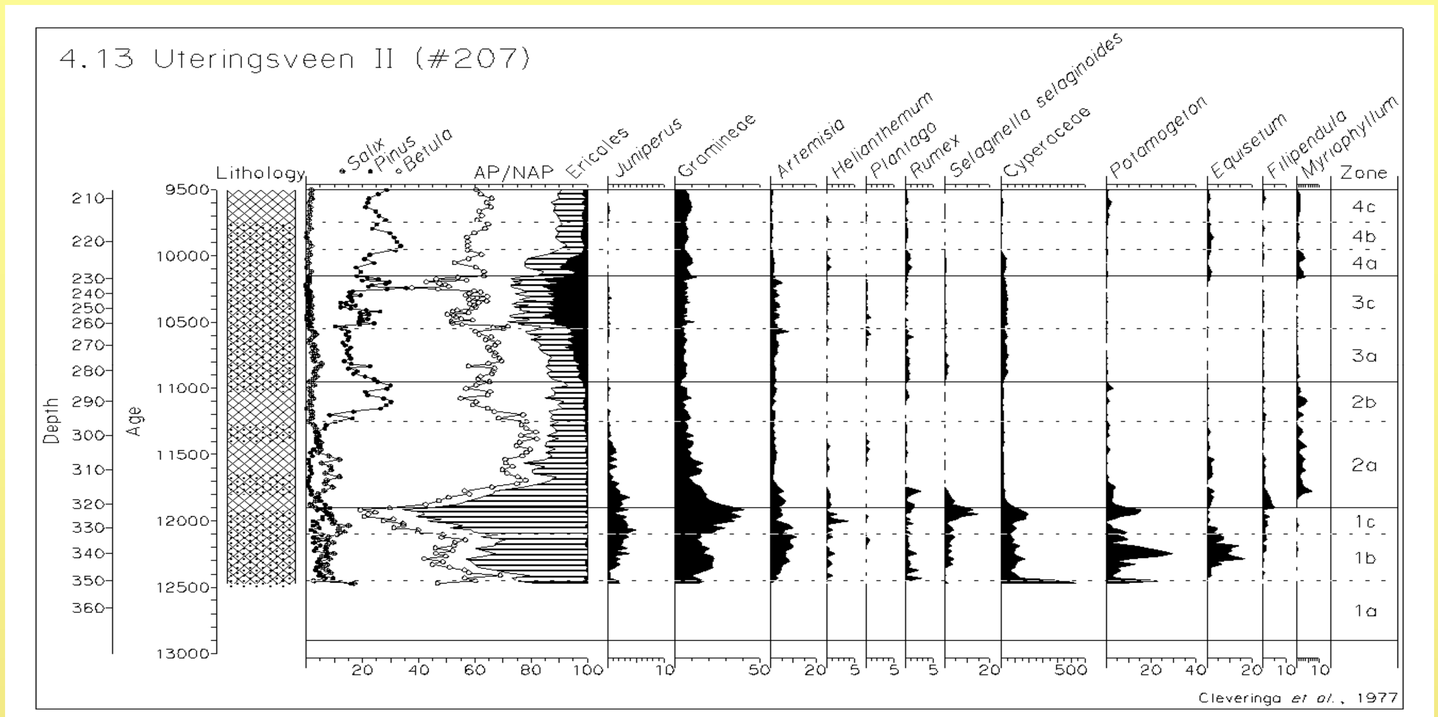

Figure 1: Pollen diagram Uteringsveen (Cleveringa et al., 1977) is an example of one of the many diagrams in The Netherlands showing a typical Lateglacial vegetation development.

Event stratigraphy

The INTIMATE group of the INQUA Palaeoclimate Commission developed an Event Stratigraphy for the North Atlantic region, based on the Greenland ice-core record (Björck *et al.*, 1998; Walker *et al.*, 1999; Lowe *et al.*, 2001; Lowe *et al.*, 2008). This scheme defines a series of stadials and interstadials for the period 23.0 to 11.5 ice-core years BP, based on marked oxygen isotope variations in the GRIP ice core. Greenland Interstadial 1 (GI-1), which is broadly correlative with the Lateglacial or Bølling-Allerød Interstadial, was subdivided into three warmer episodes GI-1a, GI-1c and GI-1e with intervening colder periods GI-1b and GI-1d.

The ages for the event boundaries are derived from the GICC05 timescale (Rasmussen *et al.*, 2006) in years b2k (= before 2000 AD). Note that this ice-core-based time-scale is different from the calibrated ^{14}C-timescale given in cal BP (=before 1950 AD). In effect, there is an offset of 50 years between the two timescales which must be taken into account when comparing ice-core years to ^{14}C-dated events.

Direct vegetation response to climate

In The Netherlands, where there are a considerable number of ^{14}C-dated Lateglacial pollen diagrams, the onset of the Lateglacial Interstadial falls between 12,500 and 12,450 ^{14}C yrs BP (Hoek, 2001). The start and end of the Younger Dryas Stadial in the Netherlands, have been dated at 10,950 and 10,150 ^{14}C yrs BP, respectively. The changes in vegetation are often coinciding with clear changes in lithology.

There is a remarkable similarity between the major zone boundaries and the transitions between GI-1, GS-1 and the Holocene, corresponding with, respectively, 12,500, 10,950, and 10,150 ^{14}C yrs BP as ^{14}C-dated in The Netherlands (see Figure 2). This is implying a direct response of vegetation to the large scale, and rapid climate changes between stadial and Interstadial conditions The smaller climate changes (such as GI-1d) appear not to be reflected directly in the vegetation development. This would mean that GI-1d is not equivalent to the Older Dryas biozone as recognised in The Netherlands and, hence, there should be another mechanism associated to these changes in vegetation composition.

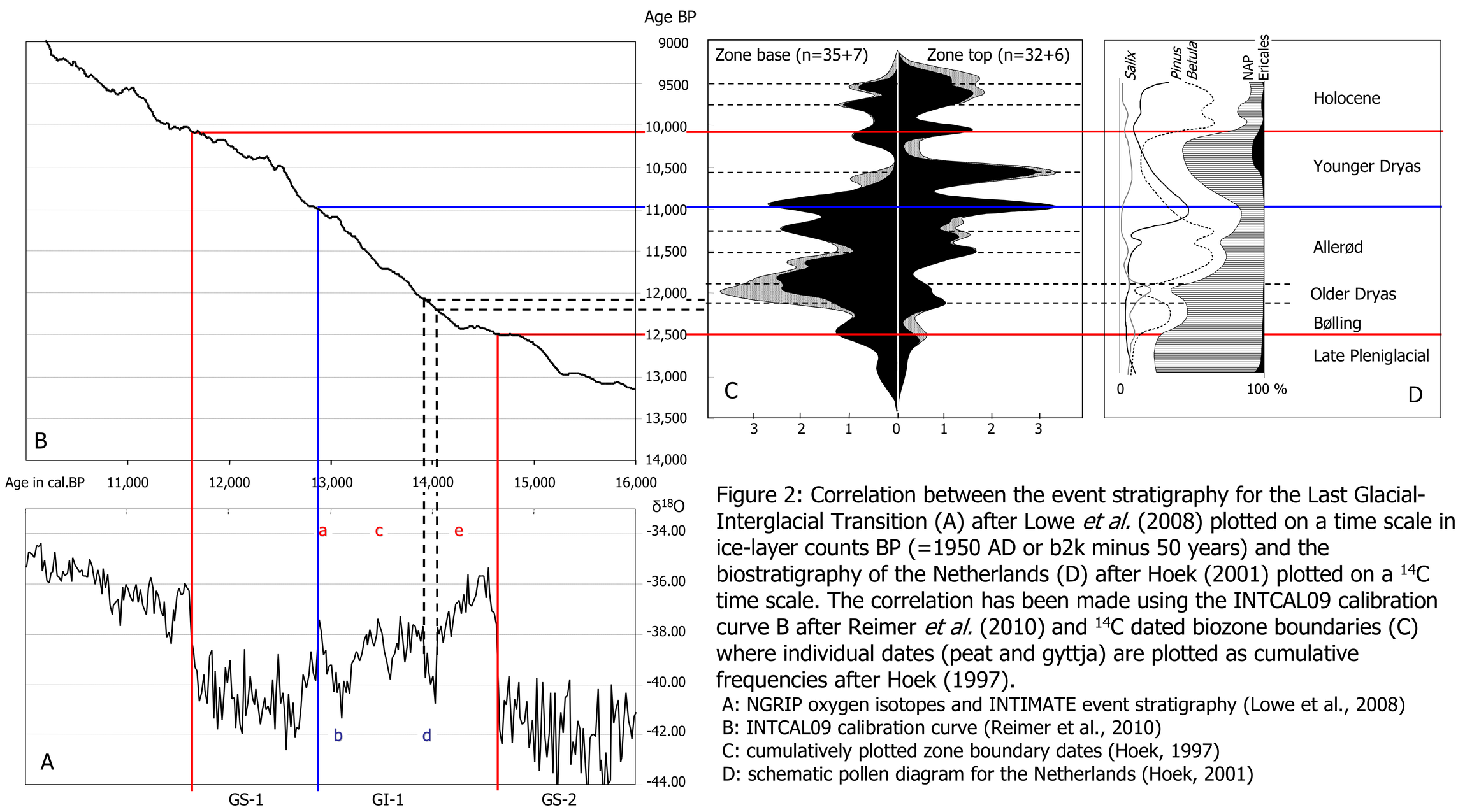

Figure 2: Correlation between the event stratigraphy for the Last Glacial-Interglacial Transition (A) after Lowe *et al.* (2008) plotted on a time scale in ice-layer counts BP (=1950 AD or b2k minus 50 years) and the biostratigraphy of the Netherlands (D) after Hoek (2001) plotted on a ^{14}C time scale. The correlation has been made using the INTCAL09 calibration curve B after Reimer *et al.* (2010) and ^{14}C dated biozone boundaries (C) where individual dates (peat and gyttja) are plotted as cumulative frequencies after Hoek (1997).

A: NGRIP oxygen isotopes and INTIMATE event stratigraphy (Lowe et al., 2008)
B: INTCAL09 calibration curve (Reimer et al., 2010)
C: cumulatively plotted zone boundary dates (Hoek, 1997)
D: schematic pollen diagram for the Netherlands (Hoek, 2001)