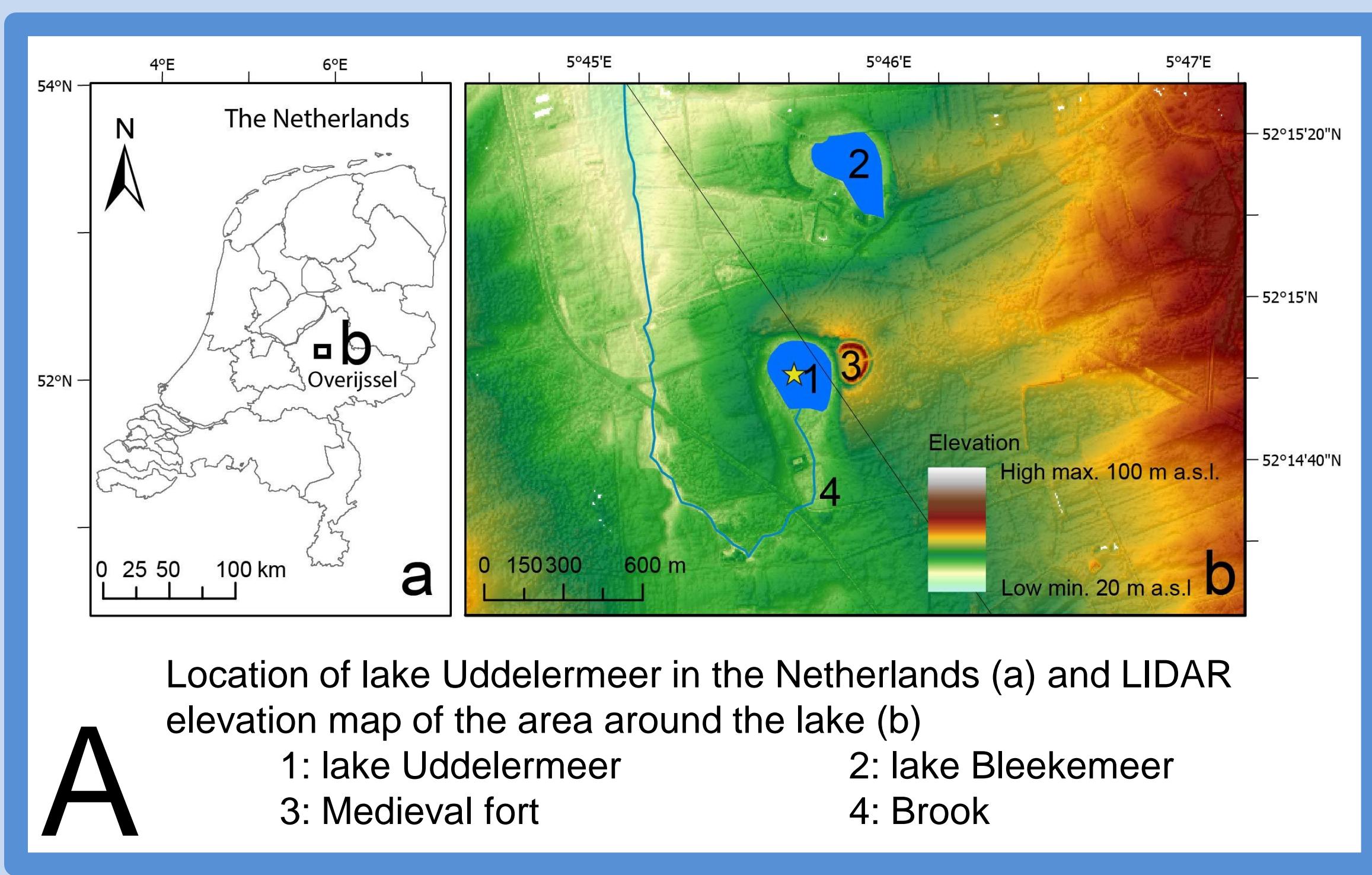




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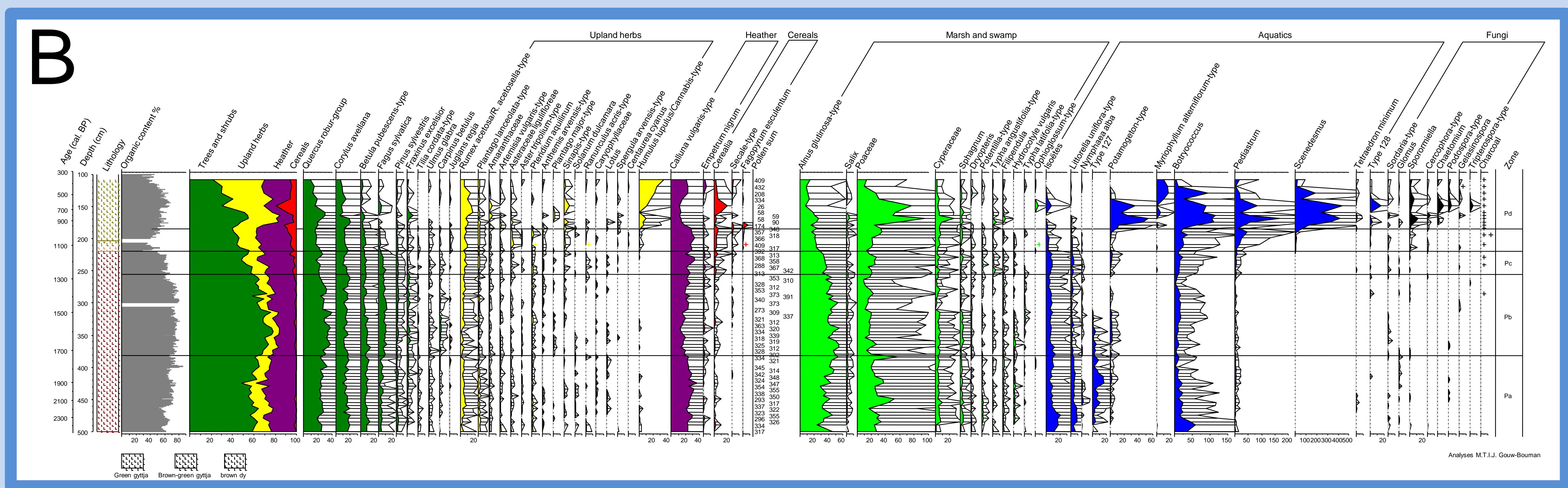
The Dark Age Cold Period

recorded in lake sediments in the Netherlands

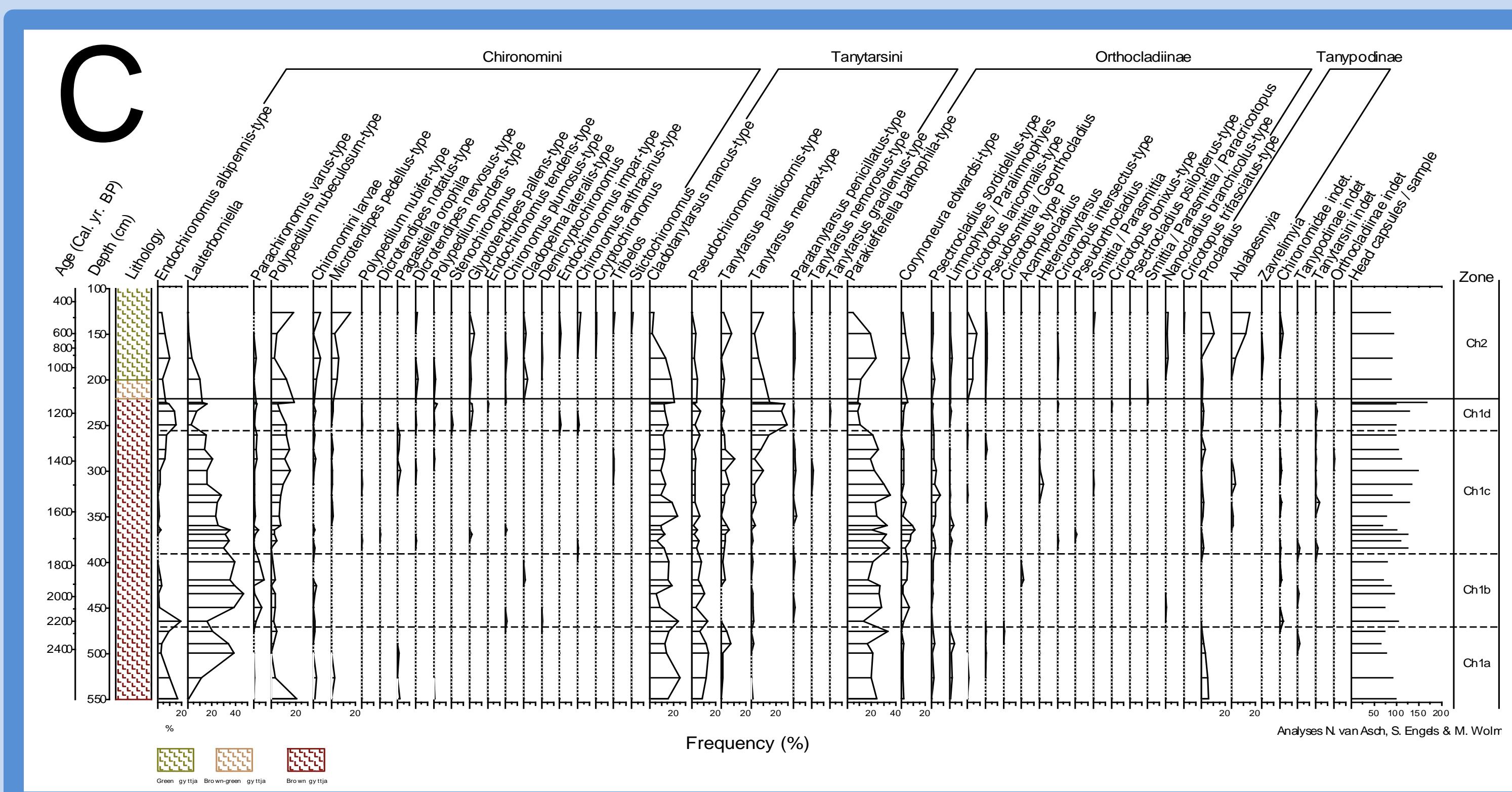
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A

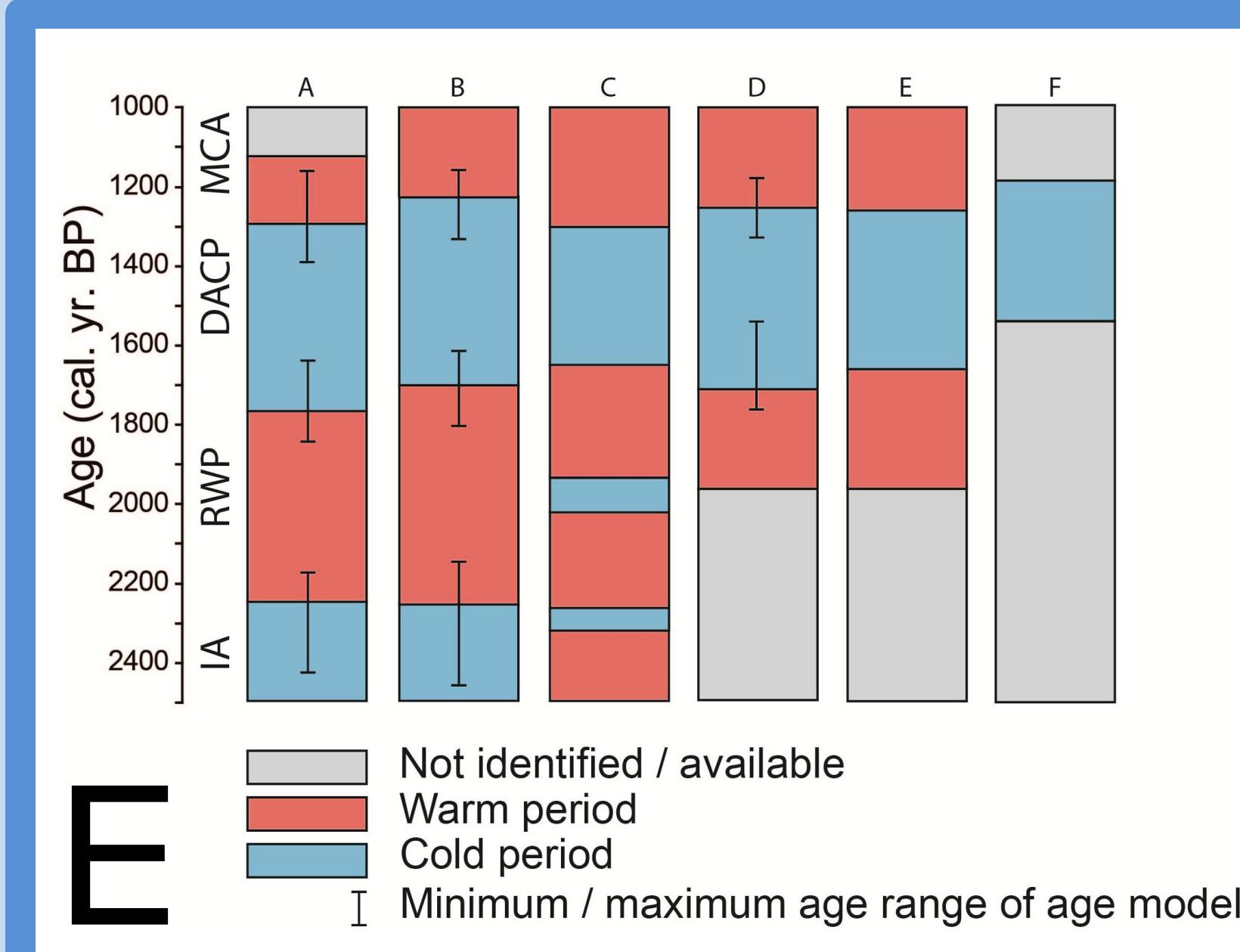
Here we present the first chironomid-inferred summer-temperature reconstruction for the late Holocene in the Netherlands. A core segment from lake Uddelermeer (Figure A) covering the period 2500 cal. yr. BP to 400 cal. yr. BP was analysed on a high-resolution for organic content, pollen, spores and NPPs (Figure B), and subfossil chironomid remains (Figure C). (Figure D). In the C-IT record, we could identify the presence of a cold Iron Age (IA), the Roman Warm Period (RWP), the Dark Age Cold Period (DACP) and the Medieval Warm Period (MWP), with a 1.5 °C temperature drop from the RWP to the DACP. These warm and cold periods have been identified in a range of proxy records throughout NW Europe indicating a regional climate trend (Figure E). In the record from lake Uddelermeer the DACP seems contemporaneous with a reforestation phase (Figure D) which is recognized in numerous palynological records throughout the Netherlands and is commonly linked to a drop in population density following the decline of the Roman Empire (Figure F). Additionally, this period appears to be characterized by large scale landscape changes in the Netherlands (Figure F). The timing of all these changes might suggest that climate developments had an (in)direct influence on landscape developments and cultural trends. The results of this study are presented in Gouw-Bouman et al. (revised/accepted) Late Holocene ecological shifts and chironomid-inferred summer temperature changes reconstructed from lake Uddelermeer, the Netherlands. Palaeo3



B Pollen, spores and chironomids (Figure C) indicate that the lake was mesotrophic and sustained a *Littorellion* in the period 2500 to 1140 cal. yr. From 1140 cal. yr. BP onward a shift to green gyttja coincides with an algal bloom indicating a shift from clear-water mesotrophic conditions to eutrophic turbid conditions in the lake. The temperature reconstruction from the eutrophic part of the profile is deemed unreliable. A reforestation is visible in zone Pb mainly attributable to *Quercus*, *Fagus* and *Alnus*. An increase in *Cannabis*-type in the top part of the core is related to hemp retting in the lake.

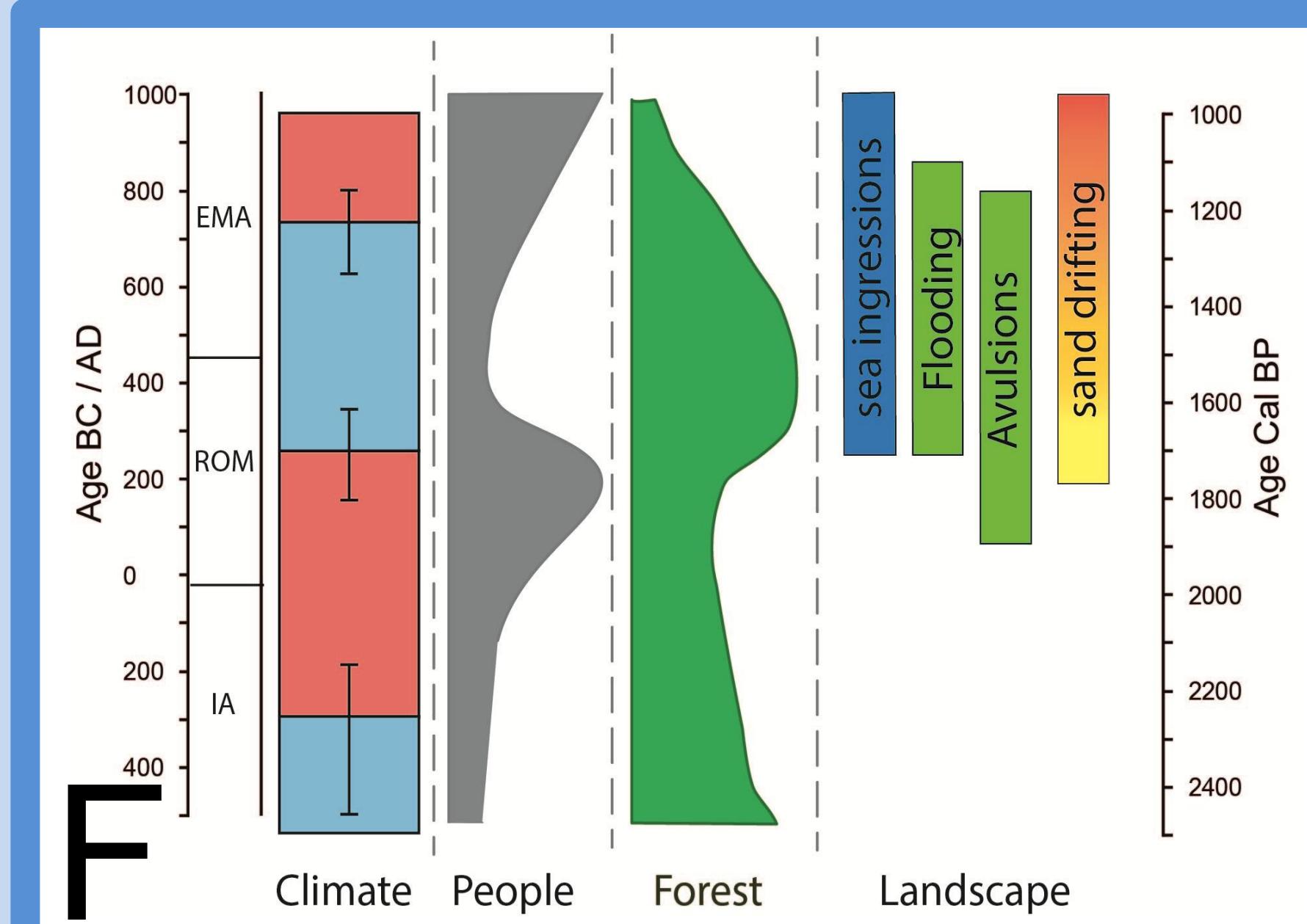


C The chironomid assemblage was mostly dominated by littoral species associated with macrophytes such as *Lauterborniella*, *Cladotanytarsus mancus*-type and *Parakiefferiella bathophila*-type. The shift to high-nutrient conditions dominated by algae at 1140 cal. yr. BP is reflected in the chironomid assemblage by increases in eurytopic taxa, such as *Procladius* and *Ablabesmyia* which are resistant to disturbances.



E NW European temperature reconstructions

- A: C-IT, lake Uddelermeer NL (Figure D)
- B: C-IT, Bigland Tarn UK (Barber et al. 2013)
- C: Tree ring inferred, Alps (Büntgen et al. 2011)
- D: Compilation various records (Riechelmann & Gouw-Bouman 2019)
- E: Compilation various records, N Hemisphere (Ljungqvist 2009)
- F: Compilation various records, global (Helama et al. 2017)



F Overview of events

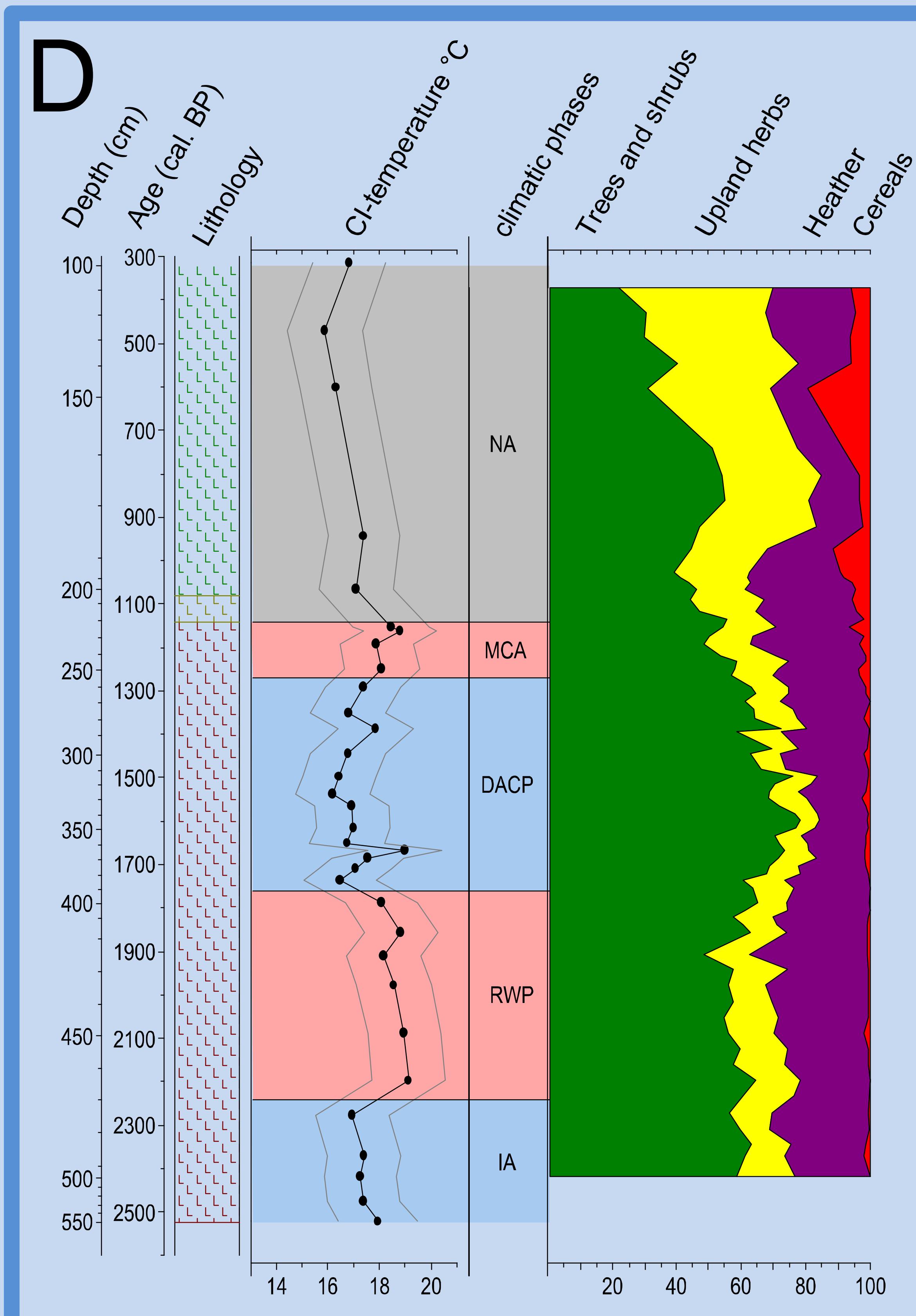
IA: Iron Age; ROM: Roman period; EMA: Early Middle Ages

Climate: C-IT lake Uddelermeer.

People: populations density in the Netherlands (Groenewoudt & van Lanen, 2018).

Forest: averaged Arboreal pollen percentages various records from the Netherlands.

Landscape: geomorphological changes (Pierik, 2017).



D Temperature and vegetation. The chironomid-inferred July air temperature (C-IT) record was produced using a Norwegian-Swiss chironomid-climate calibration dataset (Heiri et al., 2011)

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