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New tree-ring evidence for the Late Glacial period from the northern pre-Alps in eastern Switzerland

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ABSTRACT

The rate and magnitude of temperature variability at the transition from the Last Glacial Maximum into the early Holocene represents a natural analog to current and predicted climate change. A limited number of high-resolution proxy archives, however, challenges our understanding of environmental conditions during this period. Here, we present combined dendrochronological and radiocarbon evidence from 253 newly discovered subfossil pine stumps from Zurich, Switzerland. The individual trees reveal ages of 41–506 years and were growing between the Allerød and Preboreal (~13′900–11′300 cal BP). Together with previously collected pines from this region, this world's best preserved Late Glacial forest substantially improves the earliest part of the absolutely dated European tree-ring width chronology between 11′300 and 11′900 cal BP. Radiocarbon measurements from 65 Zurich pines between ~12′320 and 13′950 cal BP provide a perspective to prolong the continuous European tree-ring record by another ~2000 years into the Late Glacial era. These data will also be relevant for pinpointing the Laacher See volcanic eruption (~12′900 cal BP) and two major Alpine earthquakes (~13′770 and ~11′600 cal BP). In summary, this study emphasizes the importance of dating precision and multi-proxy comparison to disentangle environmental signals from methodological noise, particularly during periods of high climate variability but low data availability, such as the Younger Dryas cold spell (~11′700 and 12′900 cal BP).

1. Introduction

The transition from the Late Glacial (LG) into the early Holocene ~15′000–10′000 years ago has been characterized by strong climate variability (Brauer et al., 2008; Haflidason et al., 1995; Hughen et al., 2000; Johnsen et al., 1992; Lauterbach et al., 2011; Litt et al., 2001; Rasmussen et al., 2006; von Grafenstein et al., 1999; Yu and Eicher, 1998). Most lacustrine and marine sediments, as well as terrestrial pollen profiles and ice core records describe rapid warming into the Bølling (~14′700 cal BP; GI-1e; Björck et al., 1998), and again, at the onset of the Holocene (~11′650 cal BP) (Fig. 1a–c). At least three distinct cold phases occurred between ~14′050–11′650 cal BP including the Older Dryas (OD; GI-1d; Thornalley et al., 2010), Gerzensee Oscillation (GI-1b; van Raden

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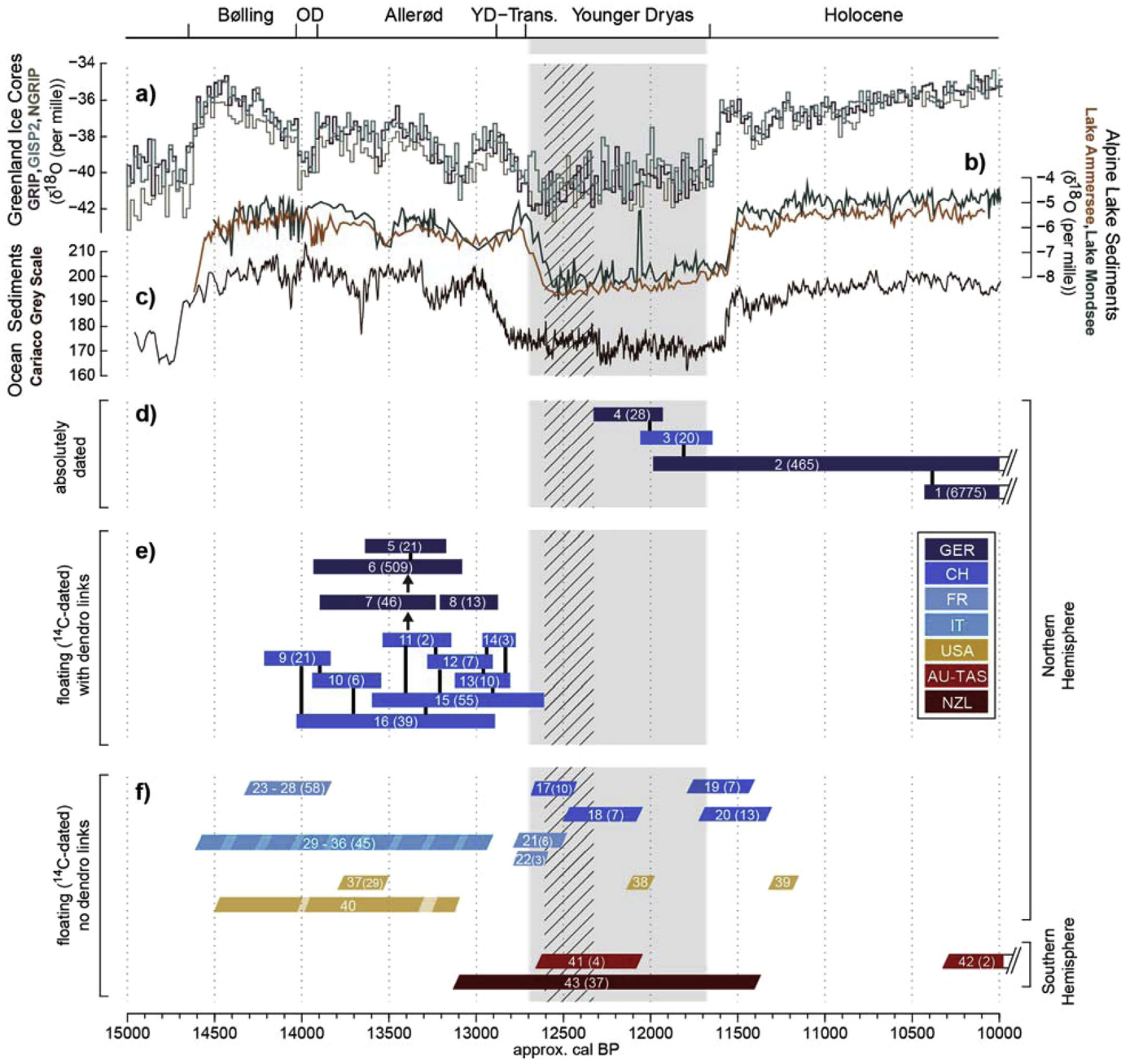

Fig. 1. Overview of Late Glacial proxy records from the Bølling into the early Holocene. (a) Greenland ice cores GRIP, GISP2 and NGRIP (Johnsen et al., 1992; Rasmussen et al., 2006, 2014; Seierstad et al., 2014), (b) Alpine lake sediments from Lake Ammersee (von Grafenstein et al., 1999) and Lake Mondsee (Lauterbach et al., 2011), and (c) marine sediments from the Cariaco Basin (Hughen et al., 2000). (d) Absolutely dated and (e–f) floating LG TRW chronologies from the Southern and Northern Hemisphere. Grey shading denotes the Younger Dryas, with dashed lines indicating the gap between the absolutely dated PPC and floating SWILM TRW chronologies. Numbers in the bars abbreviate the chronologies (see SM1 for further reference), whereas the corresponding sample size is displayed in brackets. Slanted bars refer to floating TRW chronologies, and vertical black bars show cross-dating links between chronologies.

et al., 2013), and Younger Dryas (YD; GS-1; Brauer et al., 1999) (Fig. 1a–c). Dating uncertainty of the available ice core and sediment records, however, still limits cross-comparison within and between the different paleo-archives. The timing of volcanic activity during this period, including the Laacher See Eruption (LSE) ~12′900 years ago (Baales et al., 2002; Brauer et al., 1999; Litt et al., 2003; Schmincke et al., 1999), as well as a sequence of major earthquakes (~13′770 and ~11′600 cal BP) that have been related to the deglaciation process of the Alpine arc (Strasser et al., 2006), also remain insecure.

Although not extending back into the LG period, annually resolved and absolutely dated, multi-millennial-long tree-ring width (TRW) chronologies from living and relict wood have been developed at different locations in New Zealand and Tasmania (Boswijk et al., 2006; Cook et al., 2006), north-western Siberia (Hantemirov and Shiyatov, 2002; Naurzbaev et al., 2002), and northern North America (Leavitt et al., 2006). In Europe, such composite records exist for the Austrian Alps (9111 years; Nicolussi et al., 2009), northern Germany (8000 years; Leuschner et al., 2002), Ireland (6939 years; Baillie, 2009), northern Sweden (7400