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The 8.2 ka event: Evidence for seasonal differences and the rate of climate change in western Europe

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ABSTRACT

Recent studies have drawn attention to differences in the seasonal impact of the 8.2 ka event, with longer cooler summers and shorter cooler/drier winters. However, there are no data available on the simultaneity or the rate of onset of the seasonal changes in Europe. Based on the microfacies and geochemical analyses of seasonally laminated varved sediments from Holzmaar, we present evidence of differences in duration and onset time of changes in summer temperature and winter rainfall during the 8.2 ka event. Since both summer and winter climate signals are co-registered within a single varve, there can be no ambiguity about the phasing and duration of the signals. Our data show that the onset and withdrawal of the 8.2 ka summer cooling occurred within a year, and that summer rains were reduced or absent during the investigated period. The onset of cooler summers preceded the onset of winter dryness by ca. 28 years. In view of the differences in nature and duration of the impact of the 8.2 ka event we suggest that a clearer definition of the 8.2 ka event (summer cooling or winter cooling/dryness) needs to be developed. Based on regional comparison and available modelling studies we also discuss the roles of solar variability, changes in North Atlantic Thermohaline circulation, and North Atlantic Circulation (NAO) during the period under consideration. Wavelet analyses of seasonal laminae indicates that the longer NAO cycles, linked to changes in the N. Atlantic temperatures, were more frequent during the drier periods.

1. Introduction

Understanding rates, duration, and seasonal impact of global climate changes is a key to refining climate models dealing with impact of global warming. Seasonally laminated varves are a very valuable archive as the seasonal impacts are recorded within the same varve and there can be no doubt about the phasing and duration of these changes. We discuss here an example of varved sediments from the lake Holzmaar, Germany with special focus on the 8.2 ka event that was studied using the microfacies method (Prasad et al., 2006). Previous studies (Zolitschka et al., 2000; Baier et al., 2004; Kienel et al., 2005; Prasad et al., 2006) have highlighted the sensitivity of lake Holzmaar as a proxy recorder of major climatic changes. However, the microfacies method is time consuming—it took one of us 6 months to complete microscope investigations on ca. 409 years of seasonally laminated Holzmaar sediments. To explore the possibility of an alternative, quicker method as has been used in marine sediments (e.g. Haug et al., 2001, 2003), we have investigated the same sediment sequence using µ-XRF where the measurements could be completed in a matter of weeks. Since both the investigations were made along the same transect in Holzmaar sediments we could compare the new µ-XRF data with the previously published microfacies results (Prasad et al., 2006). This combination of two different techniques allowed us to (i) test the hypothesis that elemental variations can be linked to seasonal fluctuations in the sediment input, and (ii) obtain data on the simultaneity of seasonal temperature and precipitation changes. We then discuss our findings in the broader context of climate forcings that were possibly responsible for causing the 8.2 ka event.

2. Regional setting

Lake Holzmaar (50°7′N, 6°53′E) is one of the seven lakes situated in the West Eifel volcanic field, Germany. The catchment area of the modern lake is drained by the Sammetbach that flows into lake Holzmaar. The region receives an average annual precipitation of ~730 mm both in summer and winter. Today, and also very likely in the early Holocene, the precipitation is in association with the westerly driven cyclones of Atlantic origin. The lake is dimictic and holomictic and summer anoxic conditions exist below a water depth of 15 m (Scharf and Oehms, 1992). The air temperature for the coldest month (January) is 0.1 °C, and for the warmest month is 17.4 °C (Moschen et al., 2009). The lake occasionally freezes over in the

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winter. Lower Devonian schists, greywackes, claystones and siltstones form the bedrock of the lake. Modern monitoring indicates pH increases during high summer productivity (Lücke et al., 2003; Moschen et al., 2009).

3. Materials and methods

3.1. Age model

Two overlapping sediment cores (HZM 4a, HZM 4b) were raised from the center of the lake in 1996 using a Usinger system (Mingram et al., 2005). The location of the lake and the position of different cores is shown in Fig. 1a. A composite profile from both the cores (HZM 4a/b) was prepared. An age model was developed (SP) by correlation of the HZM 4a/b composite core with the radiocarbon dated HZM B/C core (Hajdas et al., 1995) using micromarker laminae—diatom blooms or turbidite events found every 1–3 cm in all cores. Holzmaar is located 13 km southwest of the Ulmener Maar. Macrofossils from Holzmaar sediments containing ash from the Ulmener Maar eruption yielded a date of 9515 ± 75 y BP. Plant remains embedded in terrestrial tephra in another site 400 m southwest of Ulmener Maar gave an age of 9650 ± 85 y BP (Hajdas et al., 1995). The dates from the Tephra thus provide an additional check on the Holzmaar chronology.

The cores largely comprise diatom rich varved sediments. Core lithology (Zolitschka, 1998) is shown in Fig. 1b. The upper part of the cores (ca. 4 m corresponding to last 3000 years based on Hajdas et al., 1995) does not show well preserved lamination and the counting in this part is not considered reliable unless supported by additional data (Kienel et al., 2005). Our chronology is therefore based on a floating varve chronology on three core composites and is anchored to radiocarbon dates on organic matter (Fig. 1c). Thus, while the boundary of the time interval discussed below might have an uncertainty of ± 120 years (one standard deviation) inherent in ^{14}C age determination, the duration of the individual events can be expressed as varve years (see details in Prasad et al., 2006). The ages of the 8.2 ka event in Holzmaar (8057 ± 120 cal y BP) and Greenland ice cores (8150 ± 50 y) show good agreement within dating uncertainties (Prasad et al., 2006).

3.2. Sampling and chemical analyses

A series of overlapping thin sections were prepared by shock freezing, freeze drying and epoxy resin impregnation of overlapping sediment blocks. After hardening, the blocks were mounted, sawed by microtome and ground to approximately 35 µm thickness. The thin sections covering the 8.2 ka event were studied in seasonal resolution using an Axioplot Zeiss microscope. Spot checks were also carried out on parallel cores to confirm the results. The entire sequence was recounted by the same person after a gap of 2 years and the number of varves was found to be the same. Geochemical data from this study coupled with microscope observations indicated that the previously unidentified clastic fragments in some of the late summer/early fall sublaminae were calcite.

Element abundance profiling was performed on 10 cm long freeze dried and epoxy impregnated sediment blocks using an EAGLE III XL µ-XRF spectrometer (Röntgenanalytik Messtechnik GmbH, Germany). The system is equipped with a low-power air-cooled Rh X-ray tube. Tube voltage and current are adjustable to 40 kV and 1000 µA respectively. The primary X-ray beam is focussed onto the sample surface by a capillary lens with varispot function to spot sizes of 54 µm, step size of 50 µm, and counting time of 60 s. During measurements the sample was moved below the X-ray spot to predefined sample sites by the computer controlled *x*-*y*-*z* sample stage. For sample viewing two video microscopes (CCD cameras) with

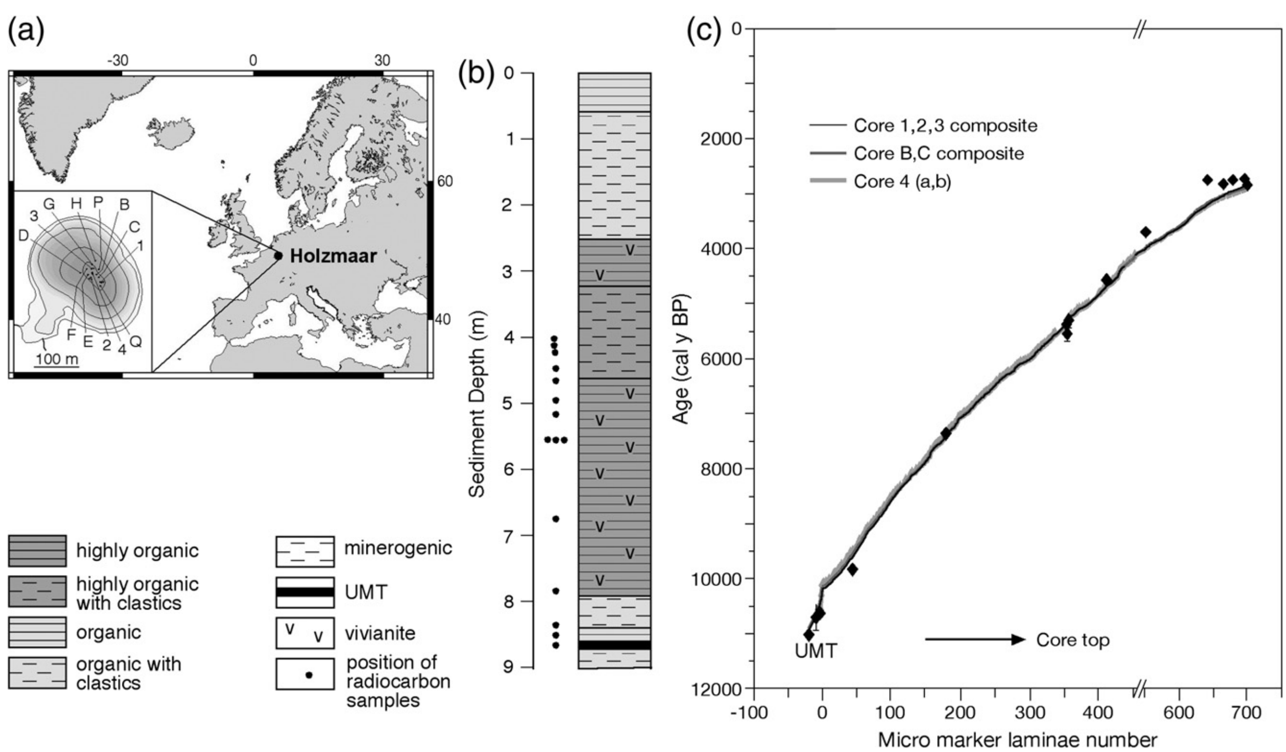

Fig. 1. (a) Location of the study area. (b) Holzmaar core lithology (modified from Zolitschka, 1998). Rein (1996) identified nearly 1000 micromarker laminae in Cores 1,2,3 composite that could be traced in the other cores as well (by SP). (c) Calibrated radiocarbon dates plotted against micromarker laminae (depth). The oldest micromarker (−20) is the Ulmener Maar tephra. In view of the slight differences in sedimentation rate revealed by the varve counting, we have plotted the radiocarbon dates against micromarker laminae. The poor quality of lamination in the upper ca. 4 m of the cores makes varve counting difficult. Micromarker laminae numbers increase towards the core top. Diamonds represent calibrated radiocarbon dates on organic matter used to develop the age model (details are available in Hajdas et al., 1995). Varve counting was done on three core composites and shows a cumulative difference of <2% for the interval shown in Fig. 1c.