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Late-Glacial climatic changes in Eastern France (Lake Lautrey) from pollen, lake-levels, and chironomids

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Abstract

High-temporal resolution analyses of pollen, chironomid, and lake-level records from Lake Lautrey provide multi-proxy, quantitative estimates of climatic change during the Late-Glacial period in eastern France. Past temperature and moisture parameters were estimated using modern analogues and 'plant functional types' transfer-function methods for three pollen records obtained from different localities within the paleolake basin. The comparison of these methods shows that they provide generally similar climate signals, with the exception of the Bölling. Comparison of pollen- and chironomid-based temperature of the warmest month reconstructions generally agree, except during the Bölling. Major abrupt changes associated with the Oldest Dryas/Bölling, Alleröd/Younger Dryas, and the Younger Dryas/Preboreal transitions were quantified as well as other minor fluctuations related to the cold events (e.g., Preboreal oscillation). The temperature of the warmest month increased by ~5°C at the start of Bölling, and by 1.5°–3°C at the onset of the Holocene, while it fell by ca. 3° to 4°C at the beginning of Younger Dryas. The comparative analysis of the results based on the three Lautrey cores have highlighted significant differences in the climate reconstructions related to the location of each core, underlining the caution that is needed when studying single cores not taken from deepest part of lake basins.

Keywords: Chironomid; Climate; Pollen; Late-Glacial

Introduction

The study of palynological data and ice-cores has shown that the transition from the last glacial period to the present interglacial (ca. 14,000–9000 ^{14}C yr B.P.; 15,000–10,000 cal yr B.P.) was a period of special 'climatic' interest characterized by alternating cold and warm intervals with rapid transitions (Björck et al., 1998). These rapid and marked climate oscillations, associated with the successive steps of the deglaciation (Johnsen et al., 2001), have also been observed in Europe from various indicators such as pollen, macrofossils, oxygen isotopes, cladocera, beetles, and chironomids (Ammann et al., 2000; Birks and Ammann, 2000; Lemdahl, 2000; Lotter et al., 1992, 2000; Von Grafenstein et al., 2000; Walker et al., 2003). Quantitative estimates of paleotemperature have been inferred from most of these proxies, providing the basis for model/data comparisons (Renssen and Isarin, 2001; Renssen et al., 2001; Vandenberghe et al., 2001). Therefore, it is crucial that proxy-based reconstructions are

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realistic and reliable, and if possible, they should be validated by independent climate reconstructions from other proxies (Birks, 2003). In the continental (i.e., non-marine) realm, pollen, coleoptera, and chironomid records appear to offer the greatest potential to generate quantified climatic data. Pollen data offer the further advantage of giving information not only on temperature but also on precipitation because plant distributions respond to changes in summer warmth, winter cold, and moisture balance. However, at times of rapid climate changes such as the Late-Glacial period the vegetation development was influenced by other factors (such as migrational lags or edaphic conditions) that may induce biases in climatic reconstruction.

Recent studies show unambiguously a direct response of the Late-Glacial vegetation to rapid climate changes in Germany, Switzerland, and the Netherlands (Ammann et al., 2000; Birks and Ammann, 2000; Brauer et al., 1999; Hoek, 2001; Williams et al., 2002). In Switzerland, the warming that occurred during the Bølling/Allerød, and the Younger Dryas cold period have been particularly well documented by multi-proxy approaches (Ammann, 2000; Ammann et al., 1994; Birks and Ammann, 2000; Lotter et al., 1992, 2000; Walker, 2001). In the French Jura, located close to the Swiss Plateau, the Late-Glacial vegetational changes characterized by a transition from an open vegetation with steppe elements to a more or less forested landscape have been well established from numerous palynological and lake records (Bégeot et al., 2000; Magny, 2001; Magny and Ruffaldi, 1995; Richard and Bégeot, 2000).

However, quantitative estimates of the Late-Glacial climate from these records are still rare. In the Swiss Jura and the French pre-Alps, high-resolution pollen and lake-level records from le Locle and St-Jorioz have been used to precisely reconstruct the climate of the Younger Dryas and early Holocene key events such as the Preboreal oscillation and the 8200 yr event (Magny et al., 2001, 2003). However, no reliable quantified climatic data that span the entire Late-Glacial are available for the Jura Mountains.

The purpose of this study is to obtain robust and precise quantitative estimates of the Late-Glacial climate of eastern France from high-resolution pollen and lake-level records taken from Lake Lautrey, Jura Mountains. We attempt to estimate the magnitude of temperature and precipitation changes at the onset and end of the Oldest and Younger Dryas, as well as during the known minor Late-Glacial oscillations at ca. 13,900, 13,000, and 11,200 cal yr B.P. This study is based on a comparative analysis of pollen data from three cores taken at different locations in the basin of the Lake Lautrey. Our objective is to examine the three palynological records, which cover the whole Late-Glacial, in particular considering the paleo-vegetation records that they provide, and their paleoclimatic interpretation. Examination of the reconstructions from different cores allows greater insight into the prevailing climatic conditions than would the results from any of the cores alone. Huntley et al. (1999) have shown that at Lago Grande di Monticchio (Italy), paleoclimate reconstructions from three pollen sequences taken at different locations exhibit apparent discrepancies in the reconstruction of the Late-Glacial climate and that the most accurate reconstruction was obtained from the mid-lake pollen record, which better represents the regional vegetation.

Furthermore, the paleoclimatic reconstructions presented here are based on a new modern pollen dataset. Samples from cold steppes and desert of the Tibetan plateau and pioneer vegetation from the Scandes Mountains have been compiled in order to limit the lack of 'good modern pollen analogues' for Late-Glacial key periods, such as the end of the Oldest Dryas and the onset of the Bølling. A comparative analysis of the inferred climate provided by two quantitative methods is proposed here. Such approaches have been successfully tested for other key periods and enable us to provide more precise and robust climate estimates than those based on only one method (Klotz et al., 2003; Lotter et al., 2000; Peyron et al., 2000). Here, the "modern analogue technique" (Guiot, 1990), and a transfer function based on "plant functional types," which is particularly efficient in no-analogue situations (Peyron et al., 1998), are used. Furthermore, the pollen-inferred summer temperature estimates will be compared with independent paleotemperatures inferred from chironomid records (Heiri and Millet, 2005).

Environmental setting

Lake Lautrey (46°35′N, 5°51E) is a small residual lake located at 788 m a.s.l. in the Jura Mountains, eastern France (Fig. 1). The climate of the Jura Mountains is semi-continental with oceanic influences. At Lake Lautrey, the mean annual temperature is 8°C, the mean temperature of the warmest month is 16°C, and annual precipitation ranges from 1650 to 1750 mm. The modern catchment area is dominated by a dense mixed forest of coniferous and deciduous trees.

Based on a detailed geophysical exploration of the lake deposits (Bossuet et al., 2000), sediment cores were taken at three different places in the former lake basin. Core 6, which was subsequently used for the multi-proxy study, is located ca. 80 m north of the present-day lake. Core 105 was extracted from the deeper part ca. 80 m northwest of the lake, and core 375 ca. 200 m southwest of the lake (Fig. 1).

The chronology of core 6 is based on twelve AMS radiocarbon dates of terrestrial macrofossils (Table 1). An age-depth model (Fig. 2) was developed for the core 6 by M. Magny (personal communication), based on these dates and on isotopic measurements of lacustrine carbonates