Quaternary Science Reviews 28 (2009) 517–525

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Chironomid and pollen evidence for climate fluctuations during the Last Glacial Termination in NW Patagonia

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A R T I C L E I N F O

Article history:
Received 31 January 2008
Received in revised form
12 November 2008
Accepted 14 November 2008

A B S T R A C T

We present chironomid and pollen records from the Huelmo site (~41°30′S), NW Patagonia, to examine in detail the timing and structure of climate changes during the Last Glacial Termination in the southern mid-latitudes. The chironomid record has the highest temporal and taxonomic resolution for this critical interval, and constitutes the first account of midge faunas at the culmination of the Last Glacial Maximum (LGM) for the region. The chironomid record suggests cold and wet conditions during the LGM, followed by deglacial warming between 17.6 and 16.8 cal kyr BP. Relatively warm conditions prevailed between ~15–14 cal kyr BP, followed by a reversal in trend with cooling pulses at ~14 and 13.5 cal kyr BP, and warming at the beginning of the Holocene. Cool-temperate conditions prevailed during the Huelmo Mascardi Cold Reversal (HMCR) which, according to chironomid data, exhibits a wet phase (13.5–12.8 cal kyr BP) followed by a conspicuous drier phase (12.8–11.5 cal kyr BP). The chironomid and pollen records from the Huelmo site indicate step-wise deglacial warming beginning at 17.6 cal kyr BP, in agreement with other paleoclimate records from NW Patagonia and isotopic signals from Antarctic ice cores. Peak warmth during the Last Glacial Termination was achieved by ~14.5 cal kyr BP, followed by a cooling trend that commenced during the Antarctic Cold Reversal, which later intensified and persisted during the HMCR (13.5–11.5 cal kyr BP). We observe a shift toward drier conditions at ~12.8 cal kyr BP superimposed upon the HMCR, coeval with intense fire activity and vegetation disturbance during Younger Dryas time.

1. Introduction

Terrestrial and marine archives from the southern mid-latitudes have identified a reversal in the warming trend at the end of the last glaciation (Heusser, 1993; Denton and Hendy, 1994; Marden, 1997; Moreno, 1997; McCulloch and Bentley, 1998; Heusser et al., 1999; Newnham and Lowe, 2000; Massaferro and Brooks, 2002; Andres et al., 2003; Lamy et al., 2004; Williams et al., 2005; Vandergoes et al., 2008). The precise timing, structure, and magnitude of this reversal, however, remain inconclusive and have led to an active discussion regarding the phasing relationship with paleoclimate records from Antarctica, Greenland, or a blend of both (Turney et al., 2003; Sugden et al., 2005). Part of the discussion originates from differences in the type and sensitivity of the individual paleoclimate proxies, as well as their location in geographic/climatic space, temporal resolution, and geochronology. Resolving this problem is important for understanding the intra- and inter-hemispheric phasing of millennial-scale climate changes during the Last Glacial Termination, and determining the climatic mechanisms involved in their initiation and propagation.

Recent studies in NW Patagonia (Fig. 1) identified a reversal in the deglacial warming trend, with cooling pulses at 14.4 and 13.5 kyr BP. Those studies indicate that cool-temperate and wet conditions persisted until 11.5 kyr BP, coeval with limnogeologic evidence for a glacial readvance of the Monte Tronador ice cap (Ariztegui et al., 1997; Moreno et al., 2001; Moreno, 2004; Moreno and León, 2003). Hajdas et al. (2003) defined the Huelmo Mascardi Cold Reversal as a period characterized by the intensification of the cooling trend between 13.5 and 11.5 kyr in the Huelmo and Mascardi lake records. Superimposed upon this pattern, the Huelmo record shows intense fire activity and concomitant vegetation disturbance between 12.8 and 11.5 kyr . This evidence was interpreted as high frequency changes in summer precipitation

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doi:10.1016/j.quascirev.2008.11.004

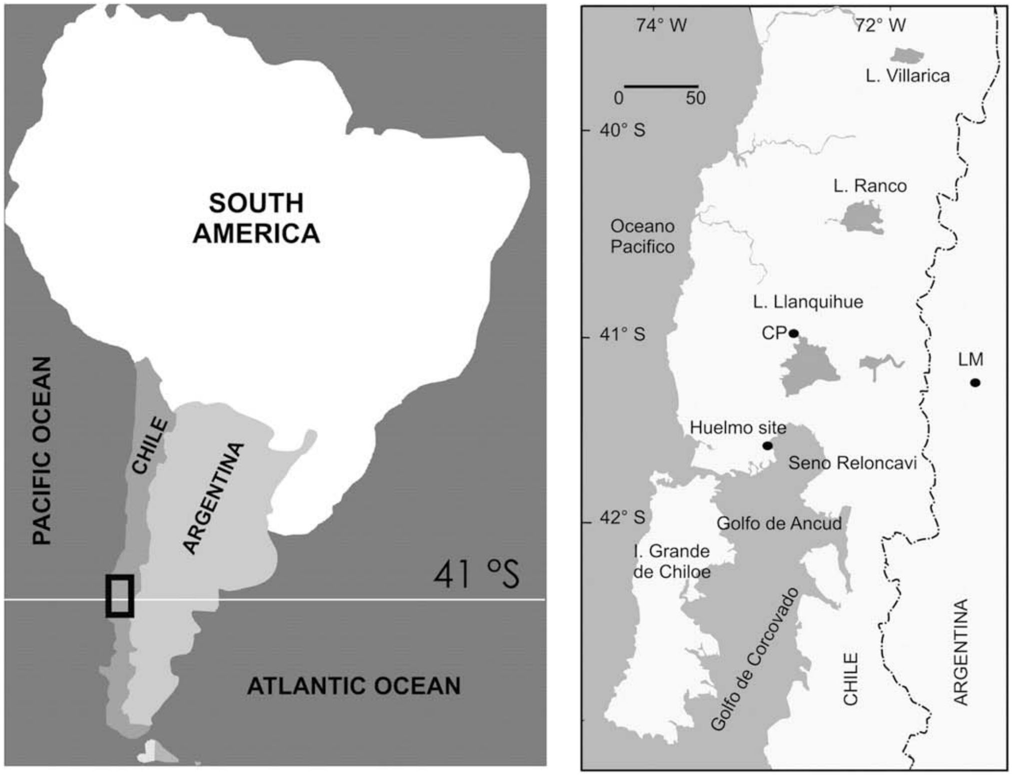

Fig. 1. Map of NW Patagonia (Chilean Lake District, Isla Grande de Chiloé, and the adjacent Andean region in Argentina) showing the location of the Huelmo, Canal de la Puntilla (CP) and Lago Mascardi (LM) sites.

under cool-temperate conditions (Moreno et al., 2001; Moreno and León, 2003). The observed complexity of changes in temperature, precipitation, disturbance regimes, and high-frequency variability changes during the Last Glacial–Interglacial Transition might account for the discrepancies observed in previous studies, highlighting the need for high-resolution, precisely dated, paleoclimate records from climatically sensitive locations.

Fossil midges (Insecta, Diptera, Chironomidae) have the potential to provide detailed paleoenvironmental reconstructions owing to their stenotopic response to climatic gradients, water depth, and trophic status. Recently published records from Central Patagonia have contributed toward deciphering multi-millennial changes in temperature and precipitation of westerly origin since the Last Glacial Maximum (LGM) (Massaferro and Brooks, 2002; Massaferro et al., 2005). These pioneer studies clearly demonstrate the sensitivity and applicability of fossil midges for unraveling the regional paleoclimate history, and for testing hypotheses of climate change.

The objective of this study was to elucidate the timing and structure of climate changes during the final portion of the LGM and during the Last Glacial Termination (LGT) in NW Patagonia (~20–10 kyr BP) using fossil chironomids as an independent indicator of paleoenvironmental change. Our study provides one of the first detailed chironomid and pollen records in the Southern Hemisphere spanning the culmination of the LGM through the LGT and into the Holocene. Here we present results of high-resolution, precisely dated chironomid, pollen, and charcoal stratigraphies from the Huelmo site (41°31'S, 73°00'W) to address several fundamental questions. 1) When did glacial maximum conditions end in this part of Patagonia?; 2) are chironomids able to detect reversals in the deglacial warming trend?; If so, 3) what was the timing and structure of those changes?; and 4) what do these results imply for understanding the LGT at hemispheric and global scales? By virtue of being a small closed-basin site, independent from the regional fluvial system, the record from Huelmo is expected to maximize local signals of environmental change. These settings are advantageous for developing paleoclimate reconstructions with high spatial and temporal resolution.

2. Materials and methods

We obtained multiple overlapping sediment cores from the center of the Huelmo mire using a square-rod Livingstone corer. The stratigraphy of the cores indicates undisturbed, continuous sedimentation in a lacustrine environment during the Late Pleistocene. A shift toward woody peat and coarse detritus gyttja at the beginning of the Holocene suggests lake level lowering and establishment of a swamp. Detailed descriptions of the site settings, core stratigraphies, radiocarbon chronology, and paleoenvironmental evolution of the site are discussed in Moreno and León (2003).

Sediment samples for this study were obtained from cores 601A (394 cm long), 9901A (342 cm long), and 9901B (430 cm long). Stratigraphic correlation among these cores was facilitated by loss-on-ignition records and two prominent tephra layers (Fig. 2a), which resulted in a 421-cm long composite stratigraphy that spans the depth interval between 1071 and 650 cm (Fig. 2b). The chronology of the spliced record is constrained by 37 AMS radiocarbon dates, which were converted to calendar yr BP using Calib 5.0 (Stuiver et al., 2005). Based on these data we developed an age model to assign an interpolated calendar age to each chironomid level. Full details of the age model are discussed in Moreno and León (2003). According to this model, the Huelmo record exhibits high sediment accumulation rates between ~20–7.8 cal kyr BP, with a mean depositional time of 23 yr/cm (median 20 yr/cm) (Fig. 2b).

For chironomid analysis, 0.5–3 cm^3 sediment samples, sufficient to obtain a minimum of 50 complete head capsules, were heated in 5% KOH for 20 min and sieved through a 90 μm mesh. Material