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Extensive recession of Cordillera Darwin glaciers in southernmost South America during Heinrich Stadial 1

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ABSTRACT

The geographic expression and phasing of events during the last termination are important for isolating mechanisms that caused Earth to emerge from the last ice age. Heinrich Stadial 1 (HS1; 14,600–18,000 yr BP) is a key because of the central role that its far-field effects had on the last termination in the Southern Hemisphere. Here, we present new data from Cordillera Darwin that show rapid glacier recession in southern South America during HS1. This retreat was coeval with ice recession elsewhere in South America and New Zealand, with increased upwelling in the Southern Ocean, with warming of SSTs offshore of Chile, and with a rise in atmospheric CO_2. Together, these data indicate a coherent and rapid response to the effects of HS1 in the middle and high latitudes of the Southern Hemisphere.

1. Introduction

Diverse climate proxies from many sectors of the globe afford a key for understanding the far-field effects of Heinrich Stadial 1 (HS1; 14,600–18,000 yr BP) during the last termination. For example, sea-surface temperature estimates show that the North Atlantic remained cold with extensive winter sea ice (Isarin et al., 1998; Denton et al., 2005; Naughton et al., 2009). Overturning circulation in the North Atlantic was reduced, leading to the greatest northward expansion of Southern Ocean deep water during the last glaciation (McManus et al., 2004). Oxygen-isotope records from ice cores indicate cold temperatures over Greenland, while at the same time Asian monsoons weakened or failed (Wang et al., 2001; Cheng et al., 2009). In contrast, southern westerly wind belts may have shifted poleward (Kaiser et al., 2005; Lamy et al., 2007; Anderson et al., 2009; Moreno et al., 2009; Denton et al., 2010), and Southern Ocean surface temperatures increased (Lamy et al., 2007; Strelin et al., 2011). Moreover, New Zealand glaciers began marked retreat at 18,000 yr BP (Denton et al., 2010; Putnam et al., 2013), at the same time that Antarctic atmospheric temperatures began to increase (Lemieux-Dudon et al., 2010). It is paradoxical that in the Southern Hemisphere this warming and ice recession took place in the face of decreasing summer insolation intensity induced by orbital variations (Mercer, 1978).

Understanding the far-field effects of HS1 may help to isolate the mechanisms responsible for the glacial–interglacial transition in the Southern Hemisphere. Here, we present data from Cordillera Darwin (54–55° S, 69–70° W; Fig. 1) that document mountain-glacier behavior in southernmost South America during HS1. Cordillera Darwin lies near the Subantarctic Front and the Drake Passage, both thought to have played an important role in ice-age terminations (i.e., Toggweiler et al., 2006; Anderson et al., 2009; Denton et al., 2010). The heavily glaciated range trends east-west and lies between the northwest arm of the Beagle Channel to the south and Seno Almirantazgo and the Straits of Magellan and adjacent channels to the north. The central peaks exceed 2000 m in elevation and support numerous glaciers that drop steeply from high ridge lines. The climate is strongly maritime. Precipitation decreases from the west, which receives several meters annually, to the east, which is considerably drier [<1 m/yr (Lliljequist, 1970; C. Porter, unpublished data)]. The region features a fjord landscape, with intervening ridges showing evidence of glacial scouring.

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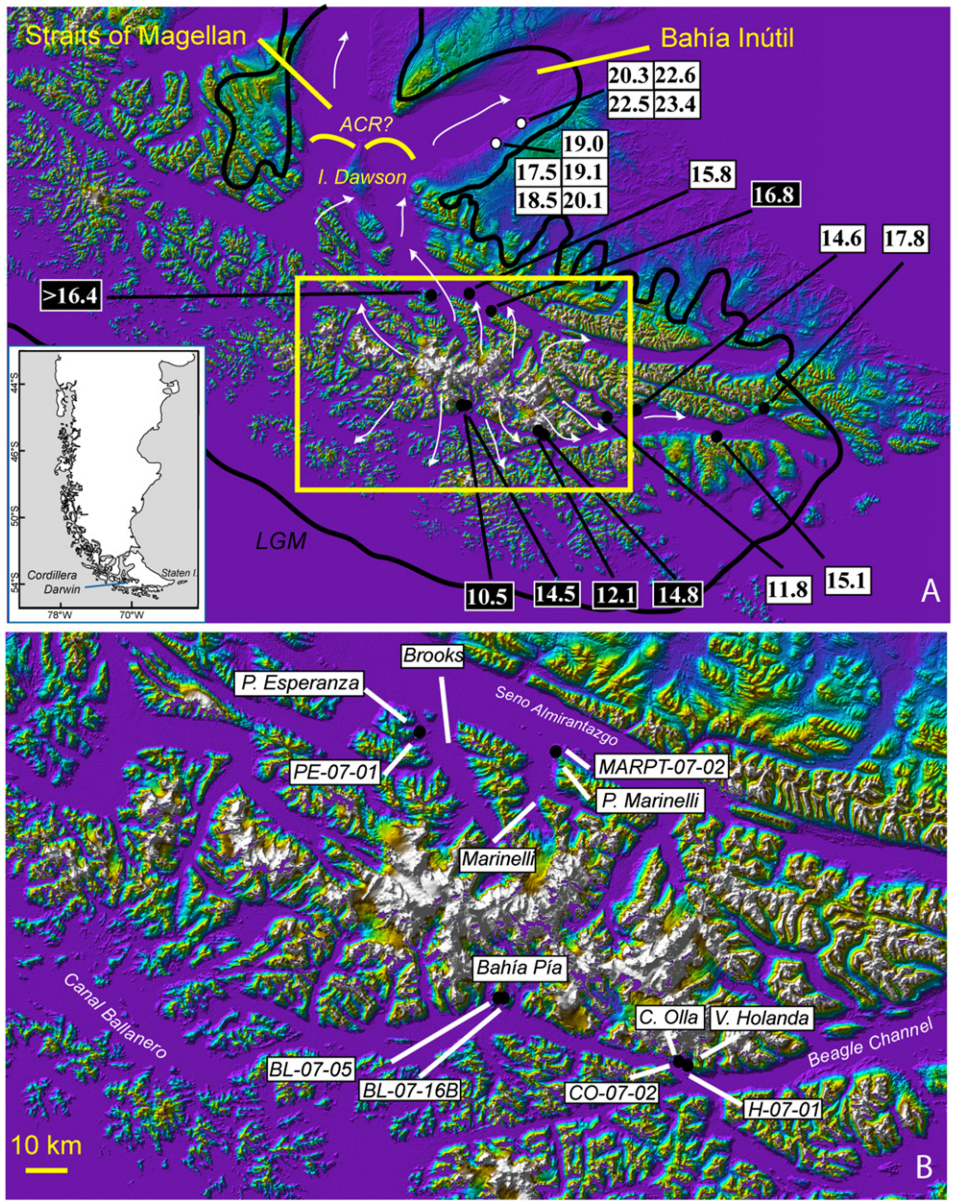

Fig. 1. (A). Index map of southern South America, showing the Cordillera Darwin field area (box, B), possible LGM limit (black; Caldenius, 1932; Rabassa et al., 2000; Coronato et al., 2009), and proposed ACR limit (yellow; McCulloch et al., 2005a,b). Also shown are minimum ages for the timing of ice recession in thousands of years, based on organic material in cores (white dots), as well as on exposure-age dates of moraines at Bahía Inútil (black dots, McCulloch et al., 2005b; Kaplan et al., 2008), as recalculated by Kaplan et al. (2011). Dates with black background are from this study; those with white background are from Boyd et al. (2008), Heusser (1989a), and Kaplan et al. (2011). White arrows show reconstructed flow directions of Rabassa et al. (2000). (B). Digital elevation model of Cordillera Darwin, showing locations of sites cored as part of this study. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Ice extent at the Last Glacial Maximum (LGM) is poorly constrained in most areas adjacent to Cordillera Darwin. However, on the north side of the mountains, moraines and erratics indicate that ice flowing northeastward from Cordillera Darwin merged with eastward-flowing ice in the Straits of Magellan and Bahía Inútil (Porter, 1990; Clapperton et al., 1995; Rabassa et al., 2000; Bentley et al., 2005; McCulloch et al., 2005b; Coronato et al., 2009). ^{10}Be surface exposure-ages of boulders on moraines, recalculated for revisions in the regional production rate (Kaplan et al., 2011), indicate that the Bahía Inútil ice lobe (Fig. 1), derived from Cordillera Darwin, remained close to its proposed LGM position until $\sim$18,400 $\pm$ 1700 yr BP (error-weighted mean of five samples; McCulloch et al., 2005b; Kaplan et al., 2008, 2011). On the south flanks of Cordillera Darwin, glaciers are thought to have radiated outward from the high peaks during the LGM and terminated near the eastern end of the Beagle Channel (Caldenius, 1932; Rabassa et al., 2000; Coronato et al., 2009). The date when the maximum position was achieved in the Beagle Channel is unknown.

Our goal was to document the timing of glacier recession deep into the heart of Cordillera Darwin as a way of determining ice-cap behavior during HS1. We concentrated on obtaining radiocarbon dates of organic material from the base of cores taken in bogs on formerly glaciated terrain. Radiocarbon dates from the base of these cores not only afford minimum-limiting ages for deglaciation, but they also preclude glacier expansion over the sites subsequent to the age of the dated horizons. After considerable probing, we obtained cores from the deepest parts of each selected bog using a square-rod piston corer. We described and sampled cores for organic materials in the field at half-centimeter intervals. We sieved the organic samples for macrofossils, which were cleaned in