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Late Glacial to Holocene terrigenous sediment record in the Northern Patagonian margin: Paleoclimate implications

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ABSTRACT

A high-resolution study of clay mineralogy and major element geochemistry has been carried out on a high sedimentation rate deep-sea core recovered off the Taitao Peninsula in southern Chili (46°S) to investigate climate and environmental changes in Northern Patagonia since the Late Glacial period (the last 22 ka BP). The chronology is based upon stable oxygen isotopes of planktonic foraminifera and AMS radiocarbon dating. Smectite/(illite + chlorite) and Ti/K ratios reveal strong changes of the sedimentary sources between the crustal rocks of the Coastal Range and the volcanic rocks of the Andean Cordillera over the last 22 ka BP. Compared to the Holocene, the Late Glacial period was characterized by reduced input of detrital material derived from the high relief of the Andean Cordillera, in agreement with a greater extension of the North Patagonian ice cap that prevented chemical weathering of basalt (smectite production) and induced physical erosion of illite and chlorite from glacial scours. The Glacial period is also characterized by rapid changes of smectite/(illite + chlorite) and Ti/K ratios indicating short-term (centennial-scale) glacier fluctuations. These changes could be the results of southern westerly shifts in the Aysen region alternating periods when glaciers were probably less fed by precipitation (mostly located in the North) and consequently less active to ice accumulation periods. The deglaciation was characterized by a trend towards warmer and more humid conditions, punctuated by a cold and arid period partly coeval with the Antarctic Cold Reversal event. Finally, the Holocene presents warmer and more humid conditions even though short term changes in the smectite/(illite + chlorite) ratio and the $\delta^{18}O$ record could be attributed to Neoglacial events in the studied region.

1. Introduction

The Southern Chilean continental margin represents one of the key areas for a better interpretation of the ocean–atmospheric circulation systems of the mid to high southern latitudes and for understanding their roles in regional and global climate change. Today, this area is under the influence of the southern westerly wind belt affecting the southern ocean circulation and consequently the global climate (Toggweiler et al., 2006; Anderson et al., 2009).

Over the last decades, the majority of studies performed in the Southern Chilean area were devoted to paleoecological and paleoclimatic reconstructions from continental and marine archives (Lowell et al., 1995; Bennett et al., 2000; Moreno, 2000, Moreno et al., 2001; Massaferro et al., 2005; Bertrand et al., 2008; Lamy et al., 2001, 2004, 2007) as well as glaciers dynamic (Denton et al., 1999; Heusser, 2002, Glasser et al., 2004). The common denominator of these studies was to understand the role of high and low latitudes in climatic forcing and their inter-hemispherical interaction by tracking amongst other things past southern westerly variability since the Late Glacial period. However, the debate remains opened about this topic, suggesting on one hand, a synchronous response of the terrestrial record from the mid-southern latitude to climatic events recorded in the North Atlantic (Lowell et al., 1995; Moreno et al., 2001). On the other hand, southern hemisphere climate changes during the glacial period in the middle and high latitudes preceded those in the northern hemisphere (Bennett et al., 2000, Lamy et al., 2004, 2007) according to methane ice-core record comparison from Antarctica and Greenland (Blunier et al., 1998, Blunier and Brook, 2001).

The present paper reports a coupled approach combining clay mineralogy and bulk sediment chemical composition from a deep-sea core collected off the North Patagonian margin at about 46°S off the fjord areas which constitute the key region influenced by strong iceberg deposits mainly during the glacial times. Until now, few studies have been consecrated to sedimentological studies on the South Chilean continental margin back to the glacial period from the southern hemisphere and most of them farther north (Lamy et al., 1999, 2004, 2007). The aim of the present study is to reconstruct the paleoenvironmental changes affecting the high latitudes of the southern hemisphere

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since the Late Glacial (the last 22 ka) through the discrimination of the sediment source(s) filling the southern Chilean margin and establishing a connection between late Pleistocene and Holocene climatic changes (glaciers advance/retreat and/or glacial/interglacial sea level changes) and the associated siliciclastic sediment response. Our record benefits of a very detailed chronological framework based on oxygen isotope analyses ($\delta^{18}O$) performed on the planktonic foraminifera *Globigerina bulloides* coupled to a large data set of AMS ^{14}C dating of foraminifera and tephra markers. Such a mineralogical and geochemical approach permits us to better document the glaciers dynamics as well as the variability of the southern westerlies since the Late Glacial period at the high latitudes of the southern hemisphere. In particular, the past evolution of the southern westerlies, their latitudinal shifts and the role played in altering the oceanic circulation represent an important starting point for a better comprehension of the climatic system mechanisms back to the glacial period in the southern hemisphere.

2. Regional setting

The studied sediment core was collected off the Chilean region of Aysen fjords between the northern Chonos Archipelago and southern Taitao Peninsula at about 46°S in the northern part of Patagonia (Fig. 1). The area is a complex island and a channel landscape formed by extensive ice erosion from the North Patagonian ice field (Norte Hielo Patagonico) that covered this region during the last glaciation and it is present today at and near the mountain top of many of the higher altitudes extending over 4200 km^2. The Aysen fjords receive freshwater mainly from the Aysén river watershed and in minor contribution by marginal rivers i.e. Rio Cisnes amongst others. Thirty outlet glaciers discharging from the North Patagonian ice field have been identified by Aniya (1988). Among them, two main glaciers from the northern part of the ice field flow to the west: Glaciar San Rafael, the lowest latitude tidewater glacier in the world, and Glaciar San Quintín, the largest outlet from Northern Patagonian ice field that ends in a piedmont lobe.

The studied region is situated within a zone of high precipitation, generated by the ocean–atmospheric control of the Southern Polar Front that moves seasonally between 50°S (summer) and 40°–45°S (winter). Low-pressure anticyclones in the Southern Pacific draw a great amount of moisture to the southern Chilean coast originating from the southern westerlies marked by an annual mean precipitation in the region in the order of 3000 mm (Fujiyoshi et al., 1987). The oceanography of the study area is characterized by a surface component represented by the cool Antarctic Circumpolar Water (ACC) which converges towards the Chilean coast between 40°S and 45°S and separates in two branches: the Peru–Chile current flowing towards the equator and the Cape Horn current moving poleward (Strub et al., 1998; Fig. 1). The deeper currents incorporate the Antarctic Intermediate Waters (AAIW between 400 and 1200 m) moving northward and, below, the Pacific Deep Water (PDW) flowing towards the southern high latitudes.

The region of Aysen fjords is also the site of the Chile triple junction area, where the present geodynamic setting is controlled by the interaction of the Antarctic, the Nazca and the South American plates. Subduction beneath the South American plate causes important volcanic activity in the Andes chain marked by thirteen Quaternary large volcanic centers, forming the southern volcanic zone SVZ (41°30 S–46°00 S; Stern

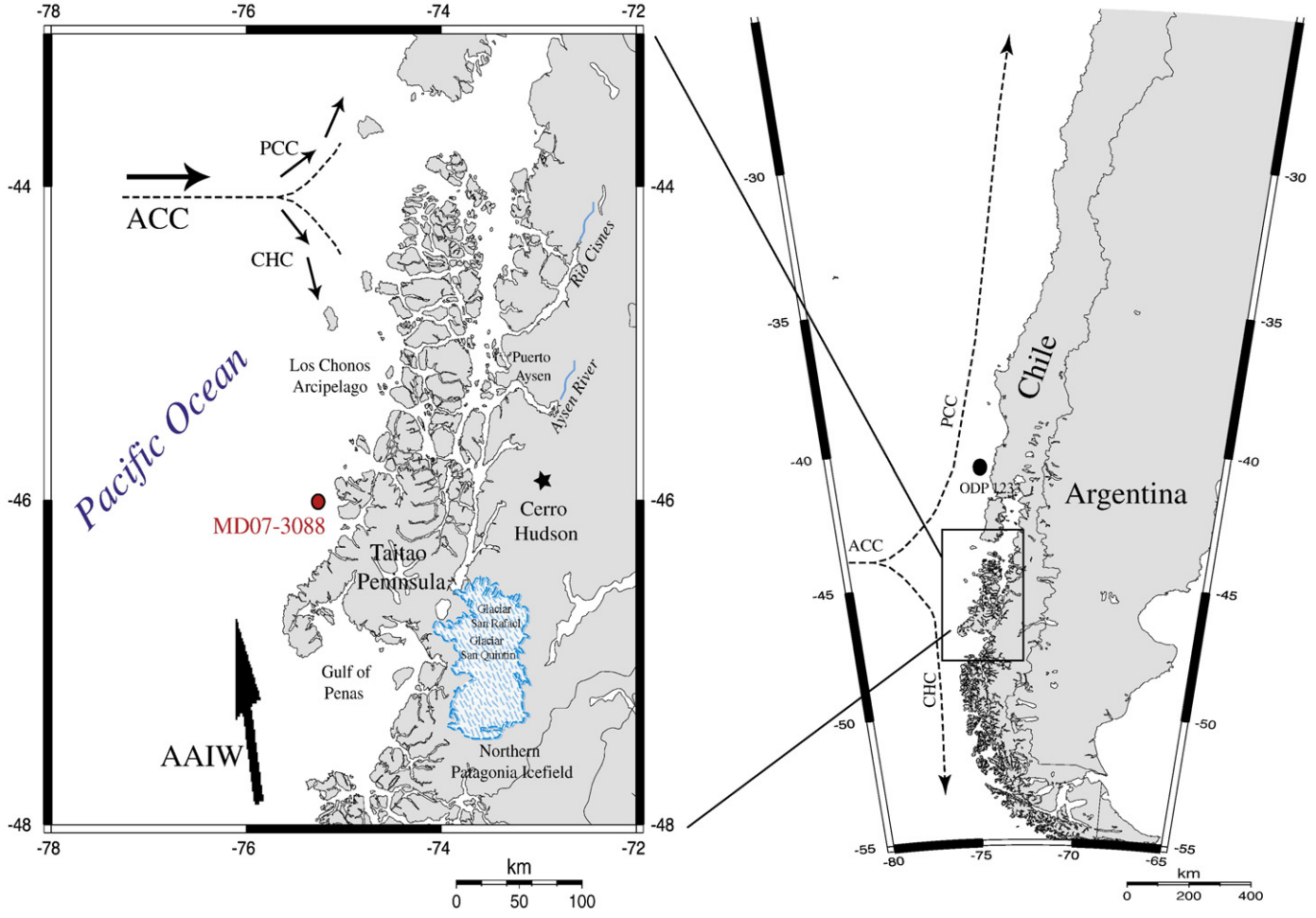

Fig. 1. Location map of the marine deep-sea core MD07-3088 and oceanographic features (ACC, Antarctic Circumpolar Current; PCC, Peru–Chili Current; CHC, Cape Horn Current; AAIW, Antarctic Intermediate Current). Location of Site ODP 1233 is shown.