Palaeogeography, Palaeoclimatology, Palaeoecology 447 (2016) 1–11

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Palaeoenvironmental change in Southern Patagonia during the Lateglacial and Holocene: Implications for forest refugia and climate reconstructions

Claudia A. Mansilla [a], Robert D. McCulloch [a], Flavia Morello [b]

[a] Biological and Environmental Science, University of Stirling, Stirling FK9 4LA, Scotland, UK
[b] Universidad de Magallanes, Instituto de la Patagonia, Centro de Estudios del Hombre Austral, Av. Bulnes, 01890 Punta Arenas, Chile

ARTICLE INFO

Article history:
Received 2 September 2015
Received in revised form 14 January 2016
Accepted 22 January 2016
Available online 29 January 2016

Keywords:
Palaeoecology
Nothofagus forest
Last Glacial–Interglacial Transition
Fuego-Patagonia

ABSTRACT

A high-resolution palynological record from Punta Yartou, Fuego-Patagonia (53°51′S; 70°08′W), supported by lithostratigraphy, radiocarbon dating and tephrochronology, was examined to reconstruct the vegetation changes during the last glacial–interglacial transition and the Holocene. Following deglaciation from the Last Glacial Maximum sometime before c. 23,070 Cal yr BP the vegetation was initially dominated by Ericaceous shrubs and following modest climate amelioration between c. 20,480 and 14,820 Cal yr BP the environment favoured the spread of *Acaena*. The trend to a warmer and more humid climate was interrupted between c. 14,820 and 13,560 Cal yr BP when the vegetation community was dominated by cold tolerant herbs such as Poaceae and Asteraceae (Subfamily Asteroideae), suggesting an open treeless landscape with colder climatic conditions coeval with the Antarctic Cold Reversal. After c. 13,560 Cal yr BP a gradual rise in temperature and humidity is inferred from the colonisation of *Nothofagus*. A further warming and increase is inferred from the establishment of the forest/steppe ecotone by c. 12,900 Cal yr BP. The early Holocene was then characterised by increasing development of *Nothofagus* open canopy forest. However, between c. 8080 and 5060 Cal yr BP there was a significant reduction in the forest cover and high values of charcoal which suggest an intense arid phase leading to increased availability of dry fuel. Between c. 5060 and 2170 Cal yr BP there were centennial-scale periods of increased wetter and colder climatic conditions. The Punta Yartou record demonstrates the sensitivity of Fuego-Patagonian forest to changes in the proximity and intensity of the southern westerly winds.

1. Introduction

The nature of climatic changes during the last glacial–interglacial transition (LGIT; c. 18,000–11,000 Cal yrs BP) in Southern South America (SSA) and the responses of vegetation communities are presently not well understood. Southern Patagonia lies athwart the southern westerly winds (SWWs), is the southernmost and largest landmass outside of Antarctica and is ideally located to study shifts in the SWWs in response to ocean–atmosphere system changes. The SWWs are a component of the global atmospheric system that has governed the palaeo and modern climate of SSA between 30°S and 60°S (Fletcher and Moreno, 2011). The SWWs drive the Antarctic Circumpolar Current (ACC), influence deep-water circulation in the Southern Ocean and have been recognised as a key factor in global atmospheric CO_2 variations (Toggweiler et al., 2006; Fletcher and Moreno, 2011). In SSA during the Last Glacial Maximum (LGM) it has been suggested that the core of the SWWs moved northward to ~45°S, bringing moister and cooler conditions, which caused the expansion of glaciers in northern Patagonia (Hulton et al., 2002). At the end of the LGM the Westerlies started to migrate southwards (McCulloch et al., 2000; Lamy et al., 2010) and they are presently focused at ~49°–53°S and during the last four decades there has been a poleward shift in westerly flow (Garreaud et al., 2013). The distribution of the Fuego-Patagonian vegetation is governed by the SWWs along the Andean mountains. This results in a strong west–east precipitation gradient, which is reflected in the spatial vegetation patterns.

In Fuego-Patagonia, the subantarctic *Nothofagus* (Southern Beech) forests have been the dominant type and may have persisted in refugia during the LGM (Margraf, 1993; Premoli et al., 2010). The limited number of long palaeoecological records from Fuego-Patagonia hinders the identification of the timing and pattern of *Nothofagus* establishment across Tierra del Fuego during the LGIT. This in turn limits our knowledge about the principle climatic factors that enable the early establishment of *Nothofagus*. Here we present new palaeoecological data to reconstruct past vegetation communities, including the early establishment of subantarctic *Nothofagus* during the LGIT for the south-west area of Isla Grande de Tierra del Fuego. This high-resolution record from Punta Yartou constrained by robust age–depth modelling enables the continuous reconstruction of forest-steppe fluctuations during the LGIT and the Holocene. The palaeoenvironmental record presented suggests a need for a reassessment of the nature and timing of warming at the termination of the last glaciation in the high-latitude regions of SSA.

http://dx.doi.org/10.1016/j.palaeo.2016.01.041
0031-0182/

2. Material and methods

2.1. Study area

Fuego-Patagonia comprises the southernmost part of South America. The site at Punta Yartou is located on the eastern shore of Canal Whiteside, in the south-western section of Tierra del Fuego (Fig. 1). The site is a deep kettle hole located just north of the major fault boundary between the Scotia and American plates. The north-west to south-east trend of the fault line is expressed through the bedrock peninsula of Punta Yartou (Sánchez et al., 2010) (Fig. 1). The coastal geomorphology of Fuego-Patagonia has been strongly influenced by glacial fluctuations during the LGM and Lateglacial (Bentley et al., 2005; McCulloch et al., 2005a, 2005b). The landscape around the study area is dominated by the presence of glacial and glacio-fluvial deposits and glacial landforms such as kettle holes, meltwater channels and moraines.

The climate of Tierra del Fuego is influenced primarily by two air masses: subpolar Antarctic air that produces cold, dry stable conditions and the oceanic SWWs that bring cold, wet and cloudy conditions. There are few available meteorological records for the region and the mean seasonal temperatures are estimated to be 9 °C January (austral summer) and 1 °C July (austral winter) (Tuhkanen et al., 1989–1990). The predominantly north–south Andean mountain range leads to orographic rainfall which creates a west–east precipitation gradient and a strong rain-shadow effect to the east of the Andes. The west to east precipitation gradient is strongly reflected in the vegetation zones (Fig. 1) (Tuhkanen et al., 1989–1990).

1) Magellanic moorland can be found on the archipelago along the southern Pacific coast (~4500– 1500 mm/yr);
2) Evergreen rainforest of *Nothofagus betuloides* dominates the western and wetter eastern flanks of the Andean cordillera (~3000–600 mm/yr). In zones where the precipitation declines to ~2000–800 mm/yr and near to the coast (below ~200 m asl.) *N. betuloides* can be found with *Drimys winteri* and *Maytenus magellanica*;
3) Magellanic deciduous forest with *Nothofagus pumilio* and *Nothofagus antarctica* in the drier areas to the east of the Andes (~900–450 mm/yr);
4) Deciduous forest/steppe ecotone along the drier eastern forest margins (~500–350 mm/yr);
5) Patagonian steppe characterised by grasses and compositae scrub that occupy the drier eastern valleys and plains (<400–350 mm/yr). Above the tree line and surrounding the ice caps Andean vegetation communities can be found.

2.2. Study site

The sample site is a closed basin within glacial till (1 km^2) at 53°51′S; 70°08′W, 51 m asl. The current mire surface is characterised by very wet peat bog vegetation dominated by Cyperaceae (sedges) and lesser amounts of *Sphagnum* spp. There are small dead stands of *N. betuloides* (tree diameter of <15 cm) on the margins of the peat bog and the trees did not have fire scars or cut marks. The current vegetation changes from the centre of the basin to the periphery, beginning with the appearance of *Acaena* spp. and *Gunnera* spp. *Berberis buxifolia* shrub dominates the slopes of the basin and higher up on the drier till surfaces and the herbs strata is largely composed of *Ribes* spp. and *Adenocaulon* spp. The landscape surrounding the basin is covered by secondary mixed evergreen-deciduous forest, dominated by *N. betuloides and N. pumilio*, with occasional stands of *D. winteri* trees. The forest shows

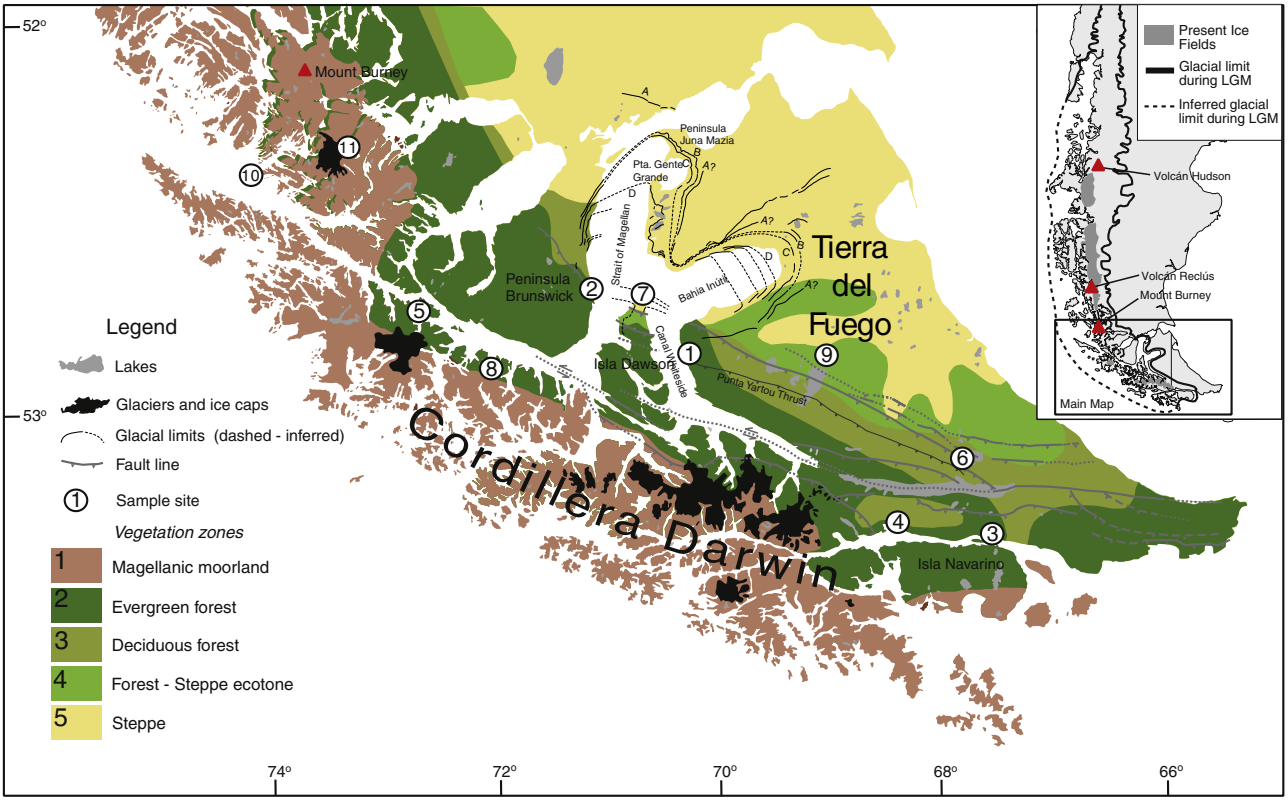

Fig. 1. Fuego-Patagonia and the principal vegetation zones (from Tuhkanen et al., 1989–1990). The limits of glacier advances into the Strait of Magellan and Bahia Inútil during glacial stages A–D are indicated (from on Bentley et al., 2005). A summary of the geological faulting in the central-eastern sector of the Strait of Magellan and Tierra del Fuego is also indicated (from Sánchez et al., 2010). Sites mentioned in the text and indicated on the map are: ① Punta Yartou; ② Puerto del Hambre; ③ Puerto Harberton; ④ Ushuaia II; ⑤ Isla Santa Inés; ⑥ Lago Yehuin; ⑦ Estancia Esmeralda II; ⑧ Isla Clarence; ⑨ Onamonte; ⑩ Lago Tamar; ⑪ Gran Campo Nevado.