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Late Pleistocene glacial stratigraphy of the Kumara-Moana region, West Coast of South Island, New Zealand

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A B S T R A C T

On the South Island of New Zealand, large piedmont glaciers descended from an ice cap on the Southern Alps onto the coastal plain of the West Coast during the late Pleistocene. The series of moraine belts and outwash plains left by the Taramakau glacier are used as a type section for interpreting the glacial geology and timing of major climatic events of New Zealand and also as a benchmark for comparison with the wider Southern Hemisphere. In this paper we review the chronology of advances by the Taramakau glacier during the last or Otira Glaciation using a combination of exposure dating using the cosmogenic nuclides ^{10}Be and ^{36}Cl, and tephrochronology. We document three distinct glacial maxima, represented by the Loopline, Larrikins and Moana Formations, separated by brief interstadials. We find that the Loopline Formation, originally attributed to Oxygen Isotope Chronozone 4, is much younger than previously thought, with an advance culminating around 24,900 ± 800 yr. The widespread late Pleistocene Kawakawa/Oruanui tephra stratigraphically lies immediately above it. This Formation has the same age previously attributed to the older part of the Larrikins Formation. Dating of the Larrikins Formation demonstrates there is no longer a basis for subdividing it into older and younger phases with an advance lasting about 1000 years between 20,800 ± 500 to 20,000 ± 400 yr. The Moana Formation represents the deposits of the last major advance of ice at 17,300 ± 500 yr and is younger than expected based on limited previous dating. The timing of major piedmont glaciation is restricted to between ~25,000 and 17,000 yr and this interval corresponds to a time of regionally cold sea surface temperatures, expansion of grasslands at the expense of forest on South Island, and hemisphere wide glaciation.

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1. Introduction

The glacial deposits of the West Coast of the South Island, New Zealand comprise one of the most complete and best described sequences in the Southern Hemisphere. The stratigraphy of the West Coast has been built on the basis of bracketing radiocarbon dates, tephrochronology, and relationships of older glacial sediments with uplifted coastal shorelines (Suggate, 1965; Suggate, 1990; Suggate and Almond, 2005). Deduction of the ages of these shorelines by correlation with deep sea δ^{18}O chronozones referenced to an orbital chronology has been central to establishing a chronostratigraphy back an estimated 15 oxygen isotope chronozones (Suggate, 1990), or more than 500,000 years.

Four major glacial advances, of progressively lesser extent, have been proposed within the last glacial cycle based on mapping and dating of glacial geomorphology on the West Coast (Suggate, 1990; Suggate and Almond, 2005). The glacial stratigraphy is underpinned by numerical ages at only a few locations. In all cases, these are not direct ages on glacial landforms, but bracketing radiocarbon ages on interbedded organic material between till and outwash, or luminescence ages on glaciofluvial landforms. Evidence of contamination casts doubt on the reliability of radiocarbon dating at some locations (Hammond et al., 1991), but the development of luminescence dating has provided a means of testing and extending the age of sediments associated with glaciation beyond 50 ka.

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However, incomplete bleaching and low sensitivity have limited the precision and spatial applicability of this method (Preusser et al., 2005). The result is that absolute dating of the glacial lithostratigraphic units on the West Coast is lacking, limiting our understanding of the timing and conditions under which these glaciers existed.

In this paper we apply the technique of exposure dating using cosmogenic nuclides to improve the dating of West Coast glacial stratigraphy. A robust stratigraphy is essential as a baseline from which to compare to other palaeoclimatic records to resolve the timing and magnitude of long term climate change, not only in New Zealand (Alloway et al., 2007), but within the wider Southern Hemisphere. We target the classic stratigraphic sequences at Kumara and Moana to establish a new chronostratigraphy for glaciation of the northern West Coast of New Zealand during the late Pleistocene. Additionally, we employ tephrochronology to provide an independent test of age. Finally, we examine the new ages within the wider context of regional and hemispheric temperature change.

2. Glacial stratigraphy

The West Coast provides an ideal location for establishing a glacial stratigraphy for New Zealand (Fig. 1). Firstly, the proximity of glaciers to the coast, combined with uplift along the Alpine Fault, has resulted in an intercalation and preservation of multiple coastal interglacial shorelines with glacial age outwash terraces. Estimates of uplift rates provide a means of placing the shorelines and corresponding glacial landforms into oxygen isotope chronozones (OIC = the informal “marine isotope stage”, Lisiecki and Raymo, 2005; Suggate, 1990). Secondly, the persistence of vegetation and peat formation throughout the last glaciation has provided carbonaceous material for radiocarbon dating, often absent elsewhere. Extensive radiocarbon dating has provided secure age estimates for buried organic layers (Suggate and Almond, 2005). Thirdly, the preservation of pollen has meant palynology has provided valuable climatostratigraphy to differentiate interglacial from glacial floras. Lastly, the local presence of the widespread Kawakawa/Oruanui tephra (KOT) (Mew et al., 1986; Almond, 1996; Lowe et al., 2008) provides a stratigraphic marker bed at 25,360 ± 80 cal yr BP (Vandergoes et al., 2013a) shortly before the last glacial maximum (LGM) that allows a wide range of sediments in different environments to be correlated (Pillans et al., 1993).

The glacial stratigraphy of the West Coast was established by Gage and Suggate (1958) who also reviewed earlier ideas on the glacial history of New Zealand. They recognised four glacial advances, with the climatostratigraphic names of the Kumara-1, -2 and -3, and Hohonu advances, based on sites around the township of Kumara, on the Taramakau and Hohonu rivers, down valley from the Otira River (Fig. 2). The advances were grouped within the Otira Glaciation, which was defined as the last glaciation, preceded by a major interglacial period.

The glacial stratigraphy and relative chronology has subsequently been repeatedly modified as further exposures have been documented, as numerical dating has improved and geological formations have been better mapped, mostly through the

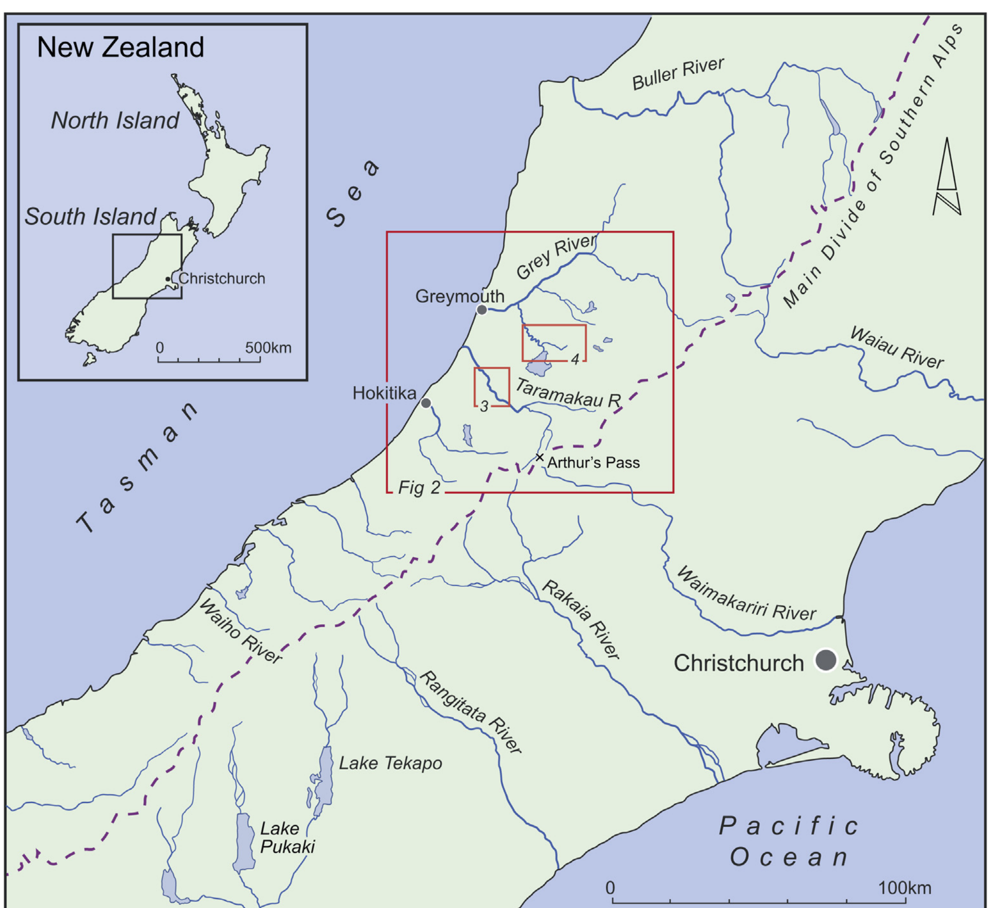

Fig. 1. Regional map of New Zealand showing locations of Figs. 2–4.

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