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Stratigraphy, optical dating chronology (IRSL) and depositional model of pre-LGM glacial deposits in the Hope Valley, New Zealand

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ABSTRACT

A 110 m thick succession of glacial valley fill is described from Poplars Gully, central South Island, New Zealand. The section consists of eight lithofacies assemblages that represent different stages of ice occupation in the valley. Basal sediments record an ice retreat phase followed by a glacial re-advance which deposited mass flow diamictons and till. A subsequent ice retreat from the site is indicated by the stratigraphic transition from till to thick glacio-fluvial gravels. This is followed by a probably short-lived glacier re-advance that caused folding and thrusting of proglacial sediments. Final glacial retreat from the valley led to the formation of a large proglacial lake. In total, Poplars Gully holds evidence for two major ice advances, separated by a glacial retreat that resulted in complete ice evacuation from the lower Hope Valley.

Infrared stimulated luminescence (IRSL) dating on ice-proximal sediments from Poplars Gully yielded six ages between 181 and 115 ka BP. Our stratigraphic logging and dating results show that the fill sequence was not, as previously thought, deposited in association with ice advances during the Last Glacial Maximum (LGM) nor indeed during the last glacial cycle. LGM glaciers later overran the fill but we find that the older glacial sequences are considerably more voluminous than those deposited during the last glacial cycle. We also show that the mid-Pleistocene glaciers carved a much deeper valley trough than did glaciers during the LGM. Taken together these features are likely to reflect a significant difference in the magnitude of successive Pleistocene glaciations in the valley, with the mid-Pleistocene ice advances having been considerably larger than those of the last glacial cycle. The recognition of the in-situ survival of extensive pre-MIS 5 (Marine Isotope Stage) deposits in valley troughs that were later occupied by LGM glaciers represents a new feature in the Quaternary stratigraphy of the Southern Alps. The results demonstrate that New Zealand's commonly very large soft-sedimentary valley fills provide a valuable, yet largely unexploited, terrestrial sedimentary archive of successive glaciations in the region.

1. Introduction

During the Pleistocene mountain glaciers in New Zealand repeatedly advanced beyond the limits of the Southern Alps reaching the coast of the Tasman Sea in the west and extending into the eastern alpine forelands (Suggate, 1990). Glacial sediments and landforms left behind cover extensive areas in New Zealand and have in recent years gained recognition as important mid-latitude Southern Hemisphere records for the interhemispheric correlation of Late Quaternary glacial events (Denton and Hendy, 1994; Broecker, 1997; Ivy-Ochs et al., 1999; Turney et al., 2003; Shulmeister et al., 2005; Barrows et al., 2007). However, major uncertainties regarding timing of glaciations and underlying climatic forcing mechanisms still exist even within different parts of the Southern Hemisphere (e.g. Kaplan et al., 2004; Glasser et al., 2006; Schaefer et al., 2006).

The geographic setting of the Southern Alps provides a case where glaciations have occurred under dominantly perhumid conditions. This is due to the orographic interception of moist westerly air masses arriving from the Tasman Sea, which commonly delivers >10,000 mm annual precipitation into the central Alps (Henderson and Thompson, 1999, Fig. 1). As a result New Zealand's past and present temperate-maritime glacier systems are characterized by a very high ice-flux and glacier tongues that descend to low elevations above sea level. Superimposed on this glacial pattern is the region's tectonic setting along

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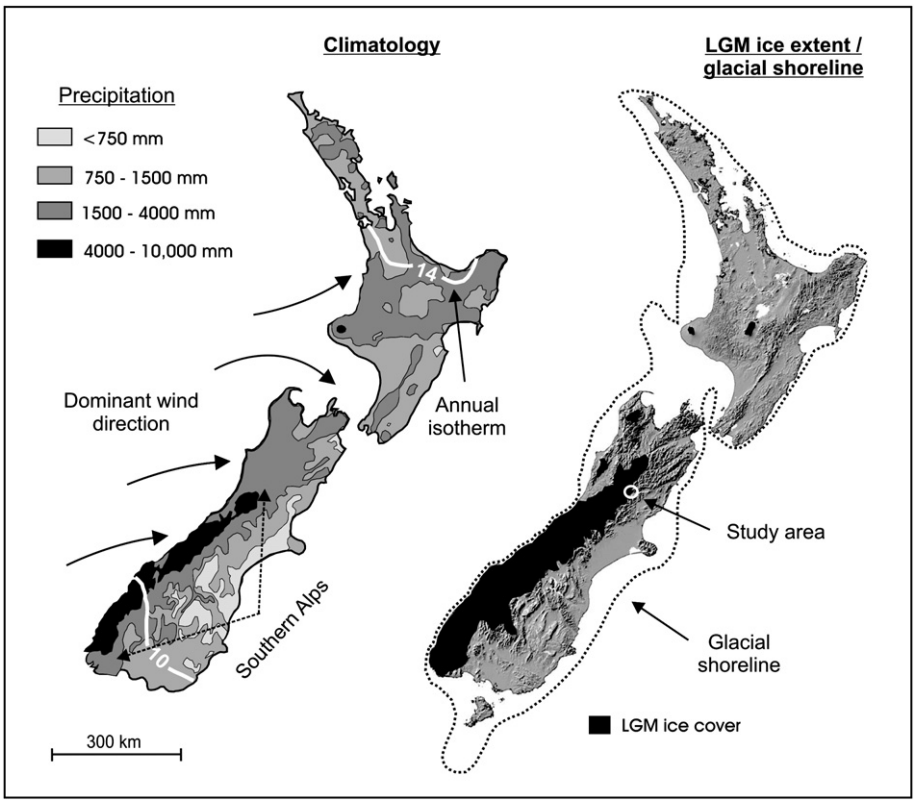

Fig. 1. New Zealand's climatic and glacial setting. Rapid tectonic uplift since the Pliocene formed the up to 3.7 km high Southern Alps along the plate margin of the Indo-Australian and Pacific Plates. The mountain range constitutes a large orographic barrier in the pathway of the mid-latitude Westerlies resulting in very high precipitation yields, particularly in the central part of the Alps. The sketch on the right shows New Zealand's approximate last glacial ice extent (LGM), the glacial shoreline and the location of the study area.

an active plate boundary, which is associated with very high rates of uplift, erosion and sediment supply (Andrews, 1973; Kamp, 1986; Norris et al., 1990).

The basic framework for discerning Late-Pleistocene mountain glaciations in the Southern Alps was established during the period 1958–1970. Work during this pioneering phase focussed on the mapping of moraine positions and the geomorphological differentiation of generations of glacial landform associations (e.g. Gage, 1958; Soons, 1963; Speight, 1963; Suggate, 1965; Clayton, 1968). Based on limited radiocarbon dating and various relative dating techniques a general chronology for Quaternary glaciations was formulated (e.g. Suggate, 1990), but major uncertainties remain regarding the absolute timings of most Quaternary glacial events.

A commonly noted feature in the Southern Alps is the presence of very voluminous valley fills. Across the Alps postglacial fluvial downcutting produced spectacular flights of terraces within these fills that often feature impressively large sedimentary exposures. Despite this, comparatively little work has been undertaken on these valley fills and glacial-depositional processes in the regional setting are poorly understood. In this paper we present stratigraphic and geochronological data from glacial sediments in the Hope Valley of North Canterbury in the South Island. Our interpretation lays emphasis on reconstructing depositional style, sequence architecture and geochronology of past ice advances and associated phases of valley aggradation.

1.1. Quaternary geology and study site

The Hope River is a tributary to the Waiau River, which drains roughly 2000 km^2 of the Southern Alps eastwards into the Pacific Ocean. The investigated valley portion west of Hanmer Basin is part of the active Marlborough Fault Zone that comprises a system of dominantly NE trending dextral strike-slip faults with average annual Quaternary slip rates in the order of 5–15 mm (Cowan, 1990; Wood et al., 1994). Present glaciation in the area is limited to a small number of cirque glaciers in the highest part of the catchment (~2300 m a.s.l.), but during the Pleistocene large valley glaciers extended 30–40 km from the headwaters. Glacial landforms in the area were first systematically investigated by Clayton (1968) who differentiated six Mid–Late-Pleistocene glacial advances. Using relative criteria these ice advances were subsequently correlated to glaciations ranging from MIS 8 to MIS 2 (Clayton, 1968; Suggate, 1990; Fig. 2).

The conceptual model based on which Pleistocene glaciations have traditionally been differentiated in New Zealand postulates that geologically recent uplift caused an increasing vertical displacement of glacial landforms through time (e.g. Gage, 1958; Suggate, 1965, 1990). Successively older glacial deposits are thus often preserved at successively higher elevations in the valley. Stacked and buried sequences of glacio-fluvial deposits are also known from many non-glaciated lower valley portions and subsiding alpine foreland basins such as the Canterbury Plains east of the Southern Alps (Moar and Gage, 1973; Brown et al., 1988; Burrows and Moar, 1996). In this paper we deal with an extensive sedimentary fill section located in the LGM glaciated portion of the Hope Valley. Because valley fill surfaces like this are often connected to LGM moraine systems, it has generally been inferred that the fills were predominantly deposited in association with the last major ice advance phase (Gage, 1958; Speight, 1963; Clayton, 1968; Maizels, 1989; Hart, 1996; Mager and Fitzsimons, 2007). This notion is also expressed in Suggate's (1965) seminal and still influential work on New Zealand glaciations where it is stated that "*owing to*