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Cosmogenic evidence for limited local LGM glacial expansion, Denton Hills, Antarctica

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A B S T R A C T

The geomorphology of the Denton Hills provides insight into the timing and magnitude of glacial retreats in a region of Antarctica isolated from the influence of the East Antarctic ice sheet. We present 26 Beryllium-10 surface exposure ages from a variety of glacial and lacustrine features in the Garwood and Miers valleys to document the glacial history of the area from 10 to 286 ka. Our data show that the cold-based Miers, Joyce and Garwood glaciers retreated little since their maximum positions at 37.2 ± 6.9 (1σ n = 4), 35.1 ± 1.5 (1σ, n = 3) and 35.6 ± 10.1 (1σ, n = 6) ka respectively. The similar timing of advance of all three glaciers and the lack of a significant glacial expansion during the global LGM suggests a local LGM for the Denton Hills between ca. 26 and 51 ka, with a mean age of 36.0 ± 7.5 (1σ, n = 13) ka.

A second cohort of exposure ages provides constraints to the behaviour of Glacial Lake Trowbridge that formerly occupied Miers Valley in the late Pleistocene. These data show active modification of the landscape from ~20 ka until the withdrawal of ice from the valley mouths, and deposition of Ross Sea Drift, at 10–14 ka.

1. Introduction

Over the last few decades, terrestrial and marine geological records provided opportunities to study changes in ice sheet volume, global sea level, and paleo-climate during glacial and interglacial cycles (Zachos et al., 2001). The Antarctic ice sheets in particular were shown to respond significantly to warming and cooling climates, particularly during and since the Last Glacial Maximum (LGM) ~ 25–19 ka (Anderson et al., 2014; Larter et al., 2014; Mackintosh et al., 2014; Ó Cofaigh et al., 2014).

A 2014 special issue of Quaternary Science Reviews (Bentley et al., 2014) comprehensively synthesised thirty years of glaciological, geological and numerical modelling studies coupled with extensive field data to suggest that during warming and cooling periods, the East and West Antarctic ice sheets (EAIS & WAIS) respond in contrasting ways. During glacial episodes, ice at the grounding line-ice shelf contact advanced into shallow coastal basins, for example the grounded expansion of the WAIS into the Ross Embayment known as the Ross Ice Sheet (RIS; Greenwood et al., 2012; Hall et al., 2013), whilst interior continental regions experienced ice thinning (Ackert et al., 2013; Joy et al., 2014; Mackintosh et al., 2014). Conversely, during warmer interglacial climates in many sectors of Antarctica the opposite occurred with coastal ice margins retreating and thinning, while ice sheet interiors thickened (Ackert et al., 2007; Joy et al., 2014; Mukhopadhyay et al., 2012).

Although the overall understanding of Antarctic ice sheet response over the Quaternary has improved, particularly for cooler periods such as the LGM, relatively little is known about the specific and localised response of the numerous, largely coastal, valley glacier systems. The advance and retreat of such glaciers is likely to be more strongly controlled by local topography and catchment precipitation rather than the larger scale of regional Antarctic ice

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sheet dynamics (Marchant et al., 1994; Swanger et al., 2017).

The complex mosaic of landscapes found throughout the ice-free areas of the Transantarctic Mountains provides an opportunity to investigate Quaternary Antarctic climate. Evidence from glacial (Denton and Marchant, 2000; Hall and Denton, 2000; Marchant et al., 1994) and paleo-lacustrine sediments (Hall et al., 2002, 2006) within the McMurdo Dry Valleys (MDV) suggest formation under a variety of climatic settings, with each valley having different glaciological, hydrological and topographic constraints. Therefore, understanding the role that geomorphic processes play in the formation of glacial valley deposits is key to their use as evidence of past Antarctic climate.

As geomorphological datasets from Antarctic mountain glaciers are rare, new datasets may provide important information about the evolution of glaciers and their relationship to climate. Additionally, the use of such datasets extends and augments other regional records, such as ice-cores and marine sediment cores, which albeit of far higher resolution than exposure age dating, pertain to atmospheric and marine systems.

Therefore, to investigate the relationship between landscape and glacial/interglacial climates prior to and following the LGM, we applied the technique of cosmogenic Beryllium-10 (^{10}Be) surface exposure dating (SED) to a variety of glacial landforms found in the Denton Hills within the MDV, an ice-free region on the western coast of McMurdo Sound (Fig. 1).

2. Regional setting

At the southern margin of the MDVs, the Denton Hills are a small ice-free and 'dry valley' region of polar desert (~200 km^2) isolated from the East Antarctic Ice Sheet to the west by the Royal Society Range and bordered to the east by the McMurdo Sound coast and Ross Ice Shelf (Fig. 1). The Denton Hills are dissected by east-trending coastal glacial valleys that drain into the western margin of the Ross Ice Shelf (RIS). The two largest valleys in the Denton Hills, the Miers and Garwood are each fed by a pair of glaciers, the Miers and Adams glaciers (Fig. 2A and B) and the Garwood and Joyce glaciers (Fig. 2C and D), respectively.

Sugden et al. (1995) suggested that, like the MDV, the valley systems of the Denton Hills were initially a product of Miocene glacial expansion. Their study showed that an advance of a warm-based EAIS into the Transantarctic Mountains that carved the region's U-shaped valleys and the subsequent overriding ice removed the majority of surficial regolith from higher elevations. However, the current valley morphology is the result of increased thickening of the RIS prior to and during the LGM, subsequent westward up-valley intrusion of grounded ice, pervasive thick permafrost conditions and development of post-LGM lacustrine and fluvial systems (Cox et al., 2012).

At the present-day, the Denton Hills are warmer than the northern Wright, Taylor and Victoria valleys and have one of the more temperate climates in Antarctica. Daily summer temperatures (December to February) ranging from −8.0 and 6.5 °C (Hawke and McConchie, 2001) with a mean of 0 °C. The area has prevailing anabatic easterly winds during summer and a noticeable absence of strong westerly katabatics that are commonly observed at other locations in the MDV (Hawke and McConchie, 2001). Cold-based glaciers within the Miers and Garwood Valleys are maintained due to low precipitation (~0.1 m a^{-1}), and limited residence time of summer snow that rapidly sublimates due to the low relative humidity (McConchie, 1989).

2.1. Glacial and lacustrine geomorphology of the Denton Hills

Miers Valley (78.1°S, 164.0°E, Fig. 1), one of the longest valleys in the Denton Hills, is ~15 km long, ~5 km wide with flanking ranges reaching elevations of >1000 masl (metres above sea level). The

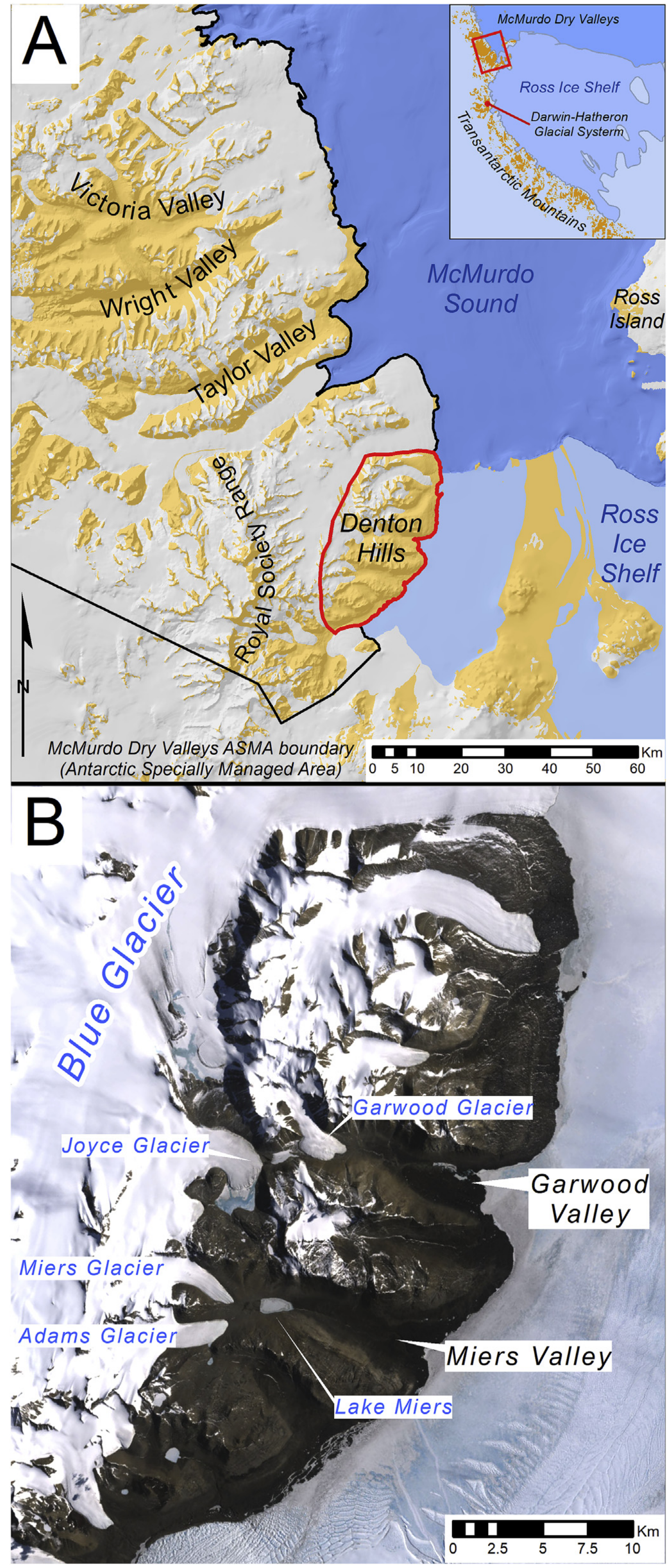

Fig. 1. McMurdo Sound, Antarctica. Area enclosed by the black line is the McMurdo Dry Valleys specially managed area, and by the red line is the Denton Hills. Also of note is another large ice-free area, the Darwin-Hatherton Glacial System, 200 km to the south. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)