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The cold climate geomorphology of the Eastern Cape Drakensberg: A reevaluation of past climatic conditions during the last glacial cycle in Southern Africa

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ABSTRACT

Southern Africa is located in a unique setting for investigating past cold climate geomorphology over glacial-interglacial timescales. It lies at the junction of three of the world's major oceans and is affected by subtropical and temperate circulation systems, therefore recording changes in Southern Hemisphere circulation patterns. Cold climate landforms are very sensitive to changes in climate and thus provide an opportunity to investigate past changes in this region. The proposed existence of glaciers in the high Eastern Cape Drakensberg mountains, together with possible rock glaciers, has led to the suggestion that temperatures in this region were as much as 10–17 °C lower than present. Such large temperature depressions are inconsistent with many other palaeoclimatic proxies in Southern Africa. This paper presents new field observations and cosmogenic nuclide exposure ages from putative cold climate landforms. We discuss alternative interpretations for the formation of the landforms and confirm that glaciers were absent in the Eastern Cape Drakensberg during the last glaciation. However, we find widespread evidence for periglacial activity down to an elevation of ~1700 m asl, as illustrated by extensive solifluction deposits, blockstreams, and stone garlands. These periglacial deposits suggest that the climate was significantly colder (~6 °C) during the Last Glacial Maximum, in keeping with other climate proxy records from the region, but not cold enough to initiate or sustain glaciers or rock glaciers.

1. Introduction

South Africa is positioned in a key location at the junction of three of the world's oceans and experiences a range of different climatic regimes owing to the influence of global circulation patterns and atmospheric processes. The magnitude of climate changes that occur in this region over glacial-interglacial cycles remains controversial, and the presence of glaciation in Southern Africa during cold periods has attracted a wide range of research over a number of decades (e.g., Sparrow, 1967; Sänger, 1988; Marker, 1991; Grab, 1996; Lewis and Illgner, 2001; Mills and Grab, 2005; Mills et al., 2009a,b, 2012; Hall, 2010). Glacial and periglacial landforms are highly sensitive to temperature and precipitation and are excellent indicators of past climate change, provided they are correctly identified. Lewis and Illgner (2001) and Lewis (2008a) proposed that small glaciers could have existed at key sites in the high Eastern Cape Drakensberg mountains as a result of topographic shading and snowblow. However, the majority of recent work concerning past glaciation has been undertaken in Lesotho (Fig. 1), where Mills et al. (2012) proposed the occurrence of small-scale glaciation at much higher elevations. Glaciation in the Eastern Cape would require a climate 10–17 °C colder than present (Lewis and Illgner, 2001) — a magnitude inconsistent with the reconstructed climate change in Lesotho.

In addition to proposed low elevation glaciation, a relict rock glacier has also been described from the Eastern Cape Drakensberg, suggesting the presence of permafrost at 1800 m asl (Lewis and Hanvey, 1993). However, Grab (2002) estimated that permafrost was only present above 3200 m asl in Lesotho. Contemporary periglacial conditions in the Eastern Cape Drakensberg are restricted to areas exceeding 2765 m asl (Kück and Lewis, 2002), and it is assumed that the last time that extensive periglacial and glacial conditions occurred is during the Last Glacial Maximum (LGM), which is defined as the period of maximum global ice volume (21 ± 2 ka; Mix et al., 2001). Climate proxy records for this period are relatively scarce for Southern Africa because of the semi- and hyperarid climates not being conducive to the preservation of long-term palaeoenvironmental records (Chase, 2009). Those that do exist broadly suggest that temperatures were lower than present by 5–7 °C (Heaton et al., 1986; Talma and Vogel, 1992; Holmgren et al., 2003), and a study in Lesotho using a glacier reconstruction and mass balance modelling approach suggested that glaciers could have

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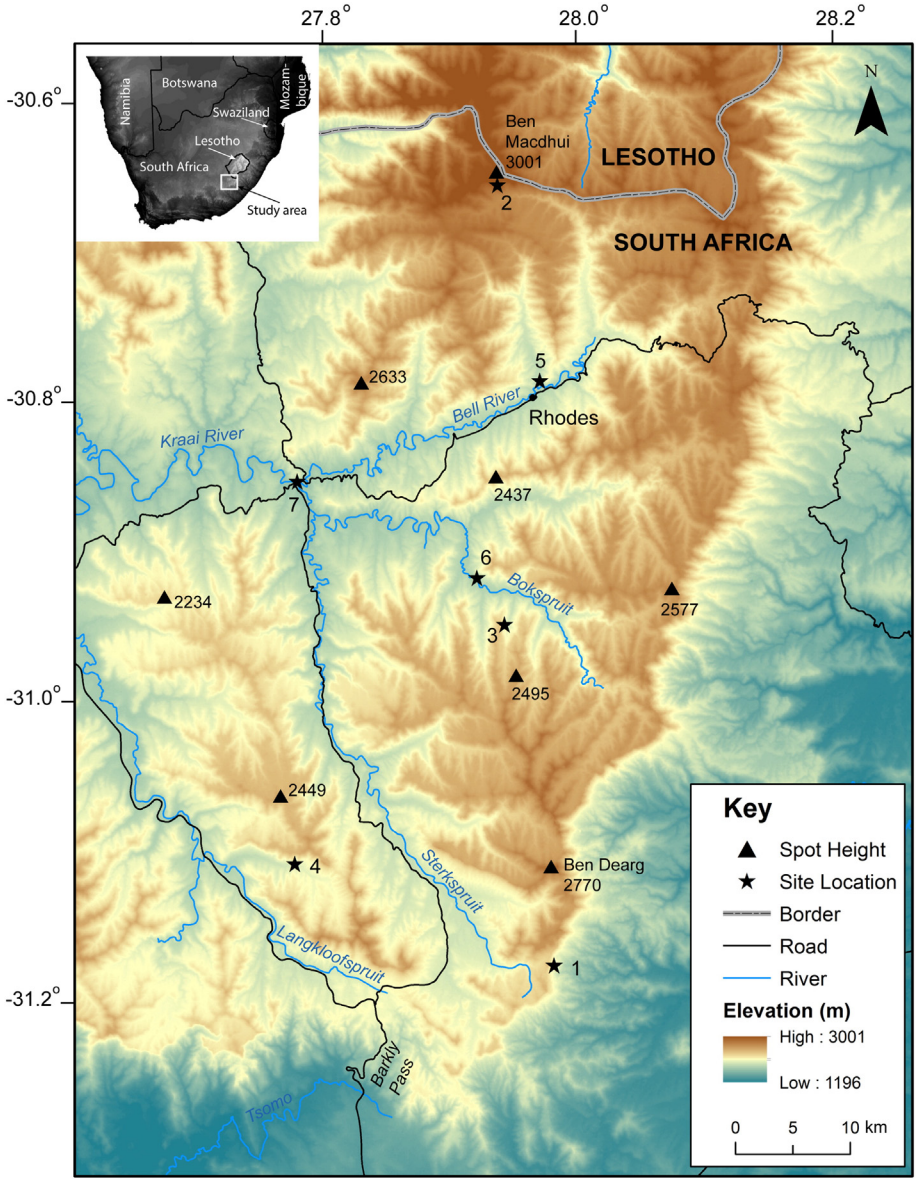

Fig. 1. Location map showing the position of the study sites (1 = Mount Enterprise, 2 = Tiffindell, 3 = Killmore, 4 = Rose Hill, 5 = Carlisle's Hoek, 6 = Bokspruit, 7 = Moshesh's Ford).

existed there under these temperature reductions (Mills et al., 2012). Estimates of palaeoprecipitation are more problematic, and the climate of Southern Africa has previously been considered as drier during the LGM (Partridge, 1997; Holmgren et al., 2003). However, more recent research has suggested that there may have been a shift in the rainfall zones allowing for increased precipitation in some areas during this time (Stuut et al., 2004; Chase and Meadows, 2007; Gasse et al., 2008; Brook et al., 2010; Mills et al., 2012; Scott et al., 2012). The extent of the shift of the rainfall zones is still poorly constrained by data, and a northward shift in the westerly wind belt would have increased the influence of the westerlies in the climate of South Africa (Chase and Meadows, 2007; Mills et al., 2012).

This paper aims to resolve the controversy regarding the extent of glaciation and cold climate processes in the Eastern Cape Drakensberg. We present the first surface exposure ages for cold climate landforms in Southern Africa. Exposure dating provides a way of extending cold climate chronologies beyond glaciated landscapes (Barrows et al., 2004) and testing hypotheses of timing of formation. We also present new geomorphological and sedimentological observations of these landforms to determine their mode of origin. Finally, this paper will present our findings within the context of the growing literature on late Pleistocene climates of Southern Africa to better constrain past temperature changes.

2. Study area

The Eastern Cape Drakensberg mountains are situated close to the Lesotho border (Fig. 1), and the highest peak in this region is 3001 m asl at Ben Macdhui. The geology of the region is composed of Beaufort and Stormberg Group sandstones and argillaceous rocks with basaltic lavas of the Drakensberg Formation occurring at higher elevations. These basaltic lavas are interbedded with sandstones, pyroclastic rocks, tuffs, and agglomerates (Geological Survey, 1983). These largely flat-lying units exert a strong control on the topography of the region. Mean annual air temperature (MAAT) at 2788 m asl is ~7.5 °C, although this is based on a limited record (1995/1996; Kück and Lewis, 2002). Freeze-thaw cycles are common at these elevations and occur on over 40% of days between May and September with an average of 63 frost