1. Introduction

Glacial landforms are widely utilised to reconstruct former glacier geometries with a common aim to estimate the Equilibrium Line Altitude (ELA) and from these, infer climatic conditions. In Britain, much of this work has focussed on Scotland during the Younger Dryas (YD; c. 12.9 – 11.7 ka BP). However, there remain large areas in upland Britain, particularly Scotland, which have not been investigated, precluding understanding of the ice-mass distribution and climate gradients during this key period.

One such area is the Tweedsmuir Hills, Southern Uplands, Scotland (55°46′N, 0°33′W). Figure 1A and B), c. 300 km². The area has traditionally been associated with an alpine style of glaciation, attributed to increasing easterly aridity, during the YD (May, 1983). At present, there are no published quantitative reconstructions of glacier-derived palaeo-climate from the Tweedsmuir Hills.

2. Methods

- Glacial landforms were digitally mapped using aerial photos, NESEXMap and field mapping (Pearce et al., 2016).
- A morphostratigraphic (landsystems) approach, 13C dating and Cosmogenic Nuclide Analysis (CNA) was employed to establish the age of the landforms.
- The 3D ice-mass geometry was reconstructed using the valley centre-line equilibrium profile model (Schilling and Hollin, 1981; Rea and Evans, 2007).
- ELAs were derived using the Area Altitude Balance Ratio method (BR = 1.67 to 2) and a BR = 1.9 ± 0.81 was used to calculate the mean icefall ELA.
- Palaeo-precipitation totals were calculated using the precipitation-temperature relationships of Ohmura et al. (1992) and Golledge et al. (2009).

3. Results

(i) Chronology

The basal 13C date (Fig. 2) suggests an early YD deglaciation in this valley, which has similarly been suggested for YD ice-masses further north in Scotland (Bromley et al., 2014).

(ii) Glacier Reconstruction

The landform replicates those attributed to the YD in many parts of Scotland, a number of which have been radiocarbon dated.

A plateau iceform is reconstructed covering c. 63 km². The mean ELA of 527 m was used to calculate the likely palaeo-climate conditions for the iceform to maintain mass-balance, using the Ohmura et al. (1992) and Golledge et al. (2010) equations and a mean summer temperature (at sea-level) of 8°C.

\( \Delta P = 2208 \pm 392 \text{ mm a}^{-1} \) (Ohmura et al., 1992)
\( \Delta P = 2336 \pm 469 \text{ mm a}^{-1} \) (Golledge et al., 2010)

3. Regional ELAs

- Tweedsmuir Hills/SE Scotland 598 8 1438 ± 258 Pa 0 m

4. Discussion

The West Highlands ice-cap covered the majority of the Scottish Highlands (c. 13,000 sq km; Figure 1). Through both cooling and relief effects it is thought that have affected accumulation beyond the ice margin. A steep easterly decline in precipitation (c. 80%) has been suggested (Golledge et al., 2008) which should have inhibited glacier sizes along this gradient.

This research demonstrates:
- A more extensive plateau icefield, rather than valley glaciation, covered the Tweedsmuir Hills. This indicates conditions were less and than previously envisaged.
- The regional ELA data indicates a rise in elevation west to east. This is likely to reflect decreasing precipitation inland during the YD as temperatures would also likely have declined along this transect.
- The YD \( \Delta P \) values determined from Ohmura et al. (1992) and Golledge et al. (2009) indicate a shallow west-east precipitation gradient but not as steep as has been suggested in the past.
- Contemporary \( \Delta P \) values suggest a steep precipitation gradient but this only appears east of the Tweedsmuir Hills. This shows a significant disparity between YD glacier-based regional climates and present day.

5. Conclusion

These results differ significantly from the traditional paradigm which assumed restricted ice-mass developed in the Tweedsmuir Hills, due to low precipitation quantities. However, when palaeo-precipitation is quantified the steep hypothesized west-east gradients fail to materialize. Indeed there appears to be a steeper precipitation gradient present-day than during the YD.

The rationale for the steep gradient was based on the assumption that the dominant storm track was from the south and southwest. The shallow gradients demonstrated here may reflect a dominant storm track from the northwest. Alternatively it may reflect seasonality contrasts, especially in precipitation timing but further work is required in order to elucidate such details.

References
