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A Younger Dryas plateau icefield in the Monadhliath, Scotland, and implications for regional palaeoclimate

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ABSTRACT

A record of Younger Dryas glaciation in Scotland is well established. However, the role of the Monadhliath, a significant plateau area extending over 840 km^2 in central Scotland, has never been investigated systematically. We present the first systematic glacial geomorphological mapping across the whole region, which has led to the identification of hitherto-unrecorded glacial and associated landforms. The spatial distribution of these landforms indicates that the last phase of glaciation in the area was that of a local plateau icefield. In addition, a clear morphostratigraphical signature provides a strong indication that the icefield dates to the Younger Dryas (12.9–11.7 ka), which is supported by numerical ages in the southeast of the study area. Based on the geomorphological evidence and 2D glacier surface profile modelling, a 280 km^2 icefield is reconstructed. A novel approach is introduced to quantify plateau icefield thickness for equilibrium line altitude (ELA) and palaeoprecipitation calculations, resulting in greater overall data confidence compared to traditional reconstruction methods. The ELA for the whole icefield is calculated to be 714 ± 25 m, whilst the ELAs of individual outlet glaciers range from 560 m in the west to 816 m in the east, demonstrating a significant W–E precipitation gradient across the region during the Younger Dryas. These ELAs compare well with those calculated for Younger Dryas ice masses reconstructed in neighbouring regions and are in good agreement with overall precipitation patterns suggested for Scotland during this time. Whilst the total amount of precipitation calculated from these ELAs is highly dependent on the method used, irrespective of this, the study suggests a more arid Younger Dryas climate in the region compared to the present day.

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1. Introduction

The Younger Dryas Stadial, equivalent to Greenland Stadial-1 (GS-1; 12.9–11.7 ka) (Rasmussen et al., 2006; Lowe et al., 2008) and correlated with the Loch Lomond Stadial (LLS) in Scotland, was a period of rapid climate change at decadal and centennial time scales (Anderson, 1997; Tarasov and Peltier, 2005; Lukas, 2011). Understanding atmospheric and oceanic drivers for rapid climate change is important in the prediction and evaluation of future climate change scenarios, especially in the amphi-North Atlantic region where detailed records document the nature of this change (e.g. Bakke et al., 2009). Scotland is a key area in this respect in that it allows linking of the terrestrial signature of Younger Dryas climatic change, manifest in numerous well-preserved glacial sediment-landform assemblages, to records from elsewhere. The evidence preserved in Scotland can be regarded as unique in a European context, largely because of absent to very limited post-depositional modification of glacial and associated sediment-landform assemblages (e.g. Benn and Lukas, 2006; Golledge, 2010). However, despite a long history of research in the Lateglacial record in Scotland, there are still numerous areas in Scotland that have not been investigated in detail and of which very little is known about the palaeoglaciology, making regional comparisons of glacier dynamics and palaeoclimate difficult and our understanding of events during the Last Glacial–Interglacial Transition (LGIT) very incomplete.

The Monadhliath (Fig. 1) are one such area, having received a very limited proportion of research attention over the last 100 years. Previous research is generally confined to the southern and eastern parts of the region only, and limited to work by British Geological Survey (BGS) officers at the beginning of the 20th Century (Barrow et al., 1913; Hinxman and Anderson, 1915), J.A.T.

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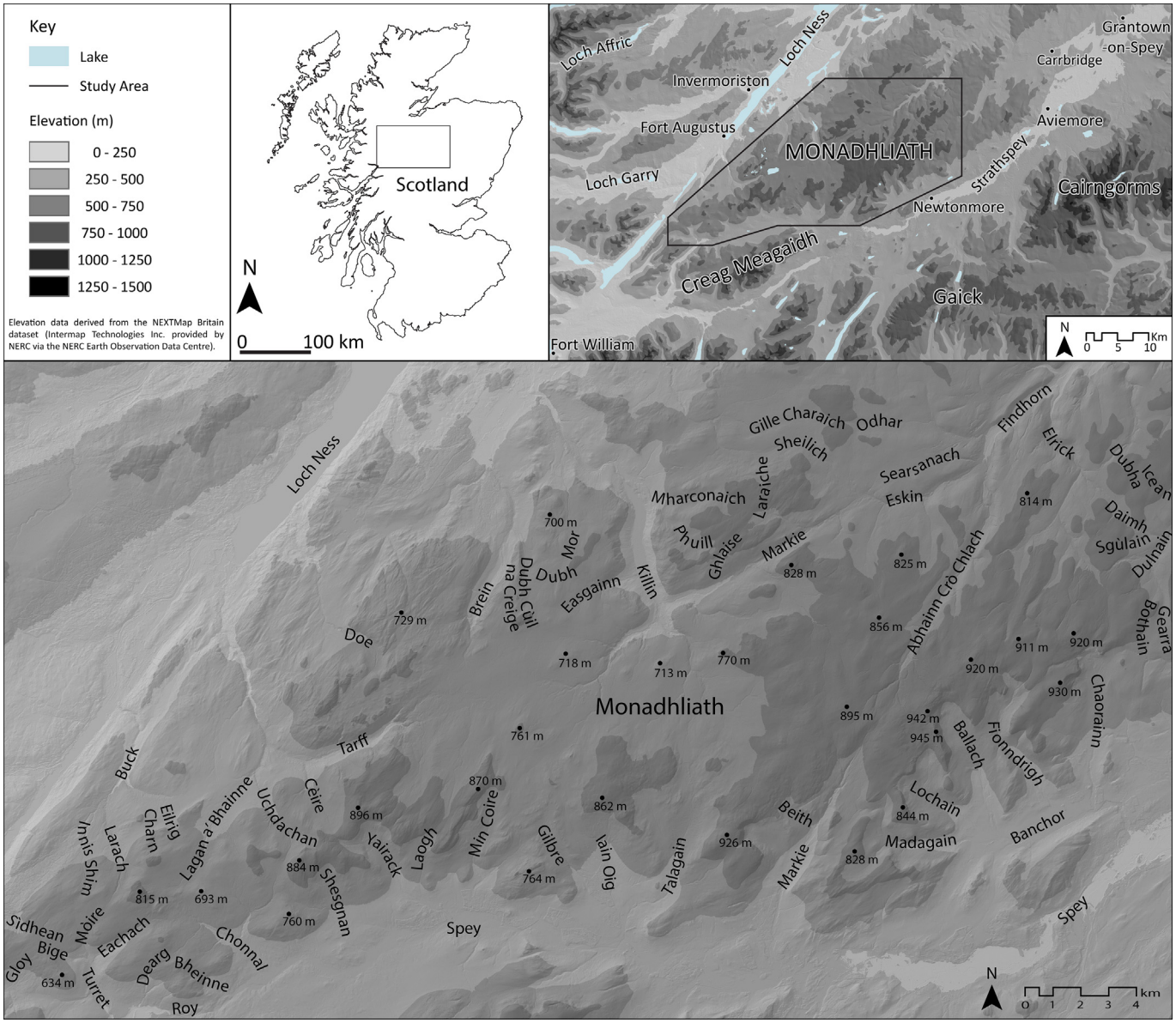

Fig. 1. Topographic map to show the location of the Monadhliath in Scotland, and all valleys referred to in Table 1 and the text. UK Outline from Ordnance Survey © Crown copyright 2010. NEXTMap DSM hillshade model from Intermap Technologies (2007).

Young in the 1970s (Young, 1977, 1978), and more recently by Auton (1998), Phillips and Auton (2000), Gheorghiu et al. (2012) and Trelea-Newton and Golledge (2012). Extensive research has however been undertaken in the adjoining region to the southwest around Glen Roy where the extent of glaciation is well established (e.g. Sissons, 1978, 1979a; Sissons and Cornish, 1983; Peacock, 1986; Lowe and Cairns, 1991; Fabel et al., 2010; Palmer et al., 2010, 2012), although the extent and timing of glaciation in Glen Turret is still subject to debate (cf. Benn and Evans, 2008; Peacock, 2009).

Recent work by Boston (2012a, b) has resulted in the first systematic mapping of the Monadhliath and the adjoining area northeast of Glen Roy (Fig. 1). This regional assessment of glaciogenic landforms and sediments provides a new insight into ice mass fluctuations and dynamics in this critical central part of the Scottish Highlands. It adds to other recent work in the region, which has hinted at the presence of a Younger Dryas plateau icefield based on numerical modelling (Golledge et al., 2008) and limited local geomorphological evidence from selected valleys (e.g. Gheorghiu et al., 2012; Trelea-Newton and Golledge, 2012), despite a traditional belief that major ice masses did not build up in the area during the Younger Dryas (Sissons, 1979b). The lack of a previous regional assessment of the field evidence, likely also hampered by the persistent paradigm that localised cirques, and not adjacent plateau surfaces, were the sole sources of any former ice masses, has meant that previous reconstructions of any ice mass have been highly tenuous; therefore, the extent and dynamics of any such ice mass in the area, if any, are currently unknown. The aims of this paper are therefore to 1) present geomorphological evidence for the presence of local plateau ice during the LGIT, 2) establish a relative chronology for glacial events in the region based on an examination of the morphostratigraphical evidence, 3) reconstruct the extent of ice masses relating to the last phase of glaciation, 4) provide estimates of former precipitation in the Central Scottish Highlands during this time based on the ice mass proportions and 5) discuss wider regional implications for palaeoclimate during the Younger Dryas.

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