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A holistic approach to the reconstruction of the dynamics of palaeo-icefields in mountainous areas – examples from the NW Highlands, Scotland

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Reconstructions of former glacier coverage and dynamics are important to our understanding of past atmosphere-cryosphere interactions and to provide input data to numerical models for the prediction of future climate change. We here present a holistic approach to the understanding of formerly glaciated areas using a combination of geomorphological and sedimentological techniques that provide the basis for palaeoglaciological and palaeoclimatic calculations. Only if all these data agree well with each other can palaeoenvironmental conditions reliably and accurately be reconstructed. Geomorphological evidence for a period of extensive mountain glaciation, dated to the Younger Dryas, is abundant in the NW Highlands of Scotland. A coherent icefield of 211 km^2 with a mean equilibrium-line altitude (ELA) of 324 m has been reconstructed from this data. According to empirical relationships at the ELA of modern glaciers the Younger Dryas palaeoprecipitation was 2358 ± 337 mm a^{-1}, implying a much wetter environment than at present. Excellent exposure conditions in moraines allow their mode of formation to be reconstructed in considerable detail so that a full understanding of ice-marginal dynamics can be gained. The vast majority of moraines represents terrestrial ice-contact fans formed by ice-marginal stacking of supraglacial debris flows and glaciofluvial units. Different stages of deformation in these fans indicate highly dynamic glaciers that oscillated during retreat. Clast shape analyses reveal that debris was mostly subglacially derived and transported prior to deposition. Comparison with modern glacial landsystems indicates that low Younger Dryas winter temperatures in Scotland were similar to those on Svalbard today, the marginal response

of Younger Dryas glaciers to temperate environments and the modes of deposition to less responsive debris-covered glaciers. High precipitation totals probably suppressed continuous permafrost development and caused high mass turnover and very dynamic, dominantly temperate Younger Dryas glaciers. Only a narrow zone around the margins appears to have been frozen to the ground, aiding elevation of basal debris and rapid deposition near the snout. These specific climatic and glaciological conditions appear not to be met by a single modern analogue.