

# Geomorphological Mapping in Wales, UK, Based on Remotely Sensed Data

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## Abstract

This paper presents the primary results from detailed geomorphological mapping of the upland areas of Cadair Idris and the Central Cambrian Mountains, Wales, UK. The mapped landforms are used to make inferences about the Quaternary glacial history of the areas. Inferences are also made concerning ice thickness, ice flow directions, Quaternary glacier thermal regimes, and the impact of glacial erosion and deposition on the surrounding landscape.

The geomorphological mapping is based on interpretation of colour aerial photographs (scale 1:10 000) and field investigations of landform/sediment associations. The data has been coupled to a new Digital Elevation Model (DEM), called NEXTMap Britain (horizontal resolution 5 m, vertical 1 m), which significantly enhance the ability to observe landforms and analyse landscape composition.

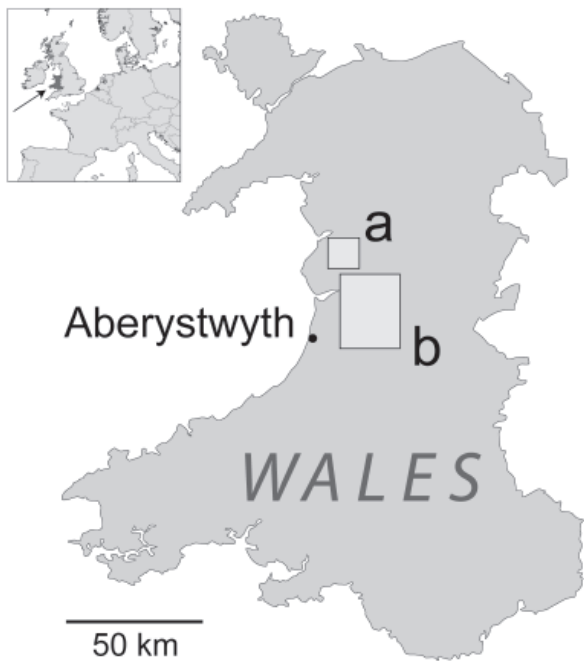
The geomorphological maps (scale 1:10 000 – 1:25 000) show spatial distribution of glacial, periglacial and postglacial features such as cirques, end moraines, striations, block fields, tors, meltwater channels, scree slopes and alluvial fans. Some of these landforms have not previously been identified, including glacial striations and subglacial meltwater channels. The new findings will add detail and support large scale reconstructions, giving us clearer insight in the palaeoglaciology of Wales. The new geomorphological data will also contribute to the geodiversity knowledge of Wales.

KEY WORDS: Cadair Idris, Central Cambrian Mountains, geomorphological mapping, palaeoglaciology, geoconservation

## 1. Introduction

Reconstructions of the last British-Irish Ice Sheet (BIIS) are often very simplistic and describe the ice mass as a configuration of several independent ice domes (Bowen et al. 2002). These reconstructions are seldom based on detailed geomorphological mapping. Reconstructions indicate that Wales was repeatedly covered by a terrestrially based Welsh Ice Cap, in addition to the Irish Sea Glacier that encroached on the coast (Hambrey et al. 2001). The Welsh Ice Cap was semi-independent from the BIIS and had several dispersion centres in the upland areas of North and Mid-Wales (McCarroll and Ballantyne 2000).

To aid palaeoglaciological reconstructions, detailed geomorphological mapping based on remote sensing has been executed in contrasting upland areas in Mid-Wales (Fig. 1). The aim is to determine the dynamics and palaeotopography of former Welsh ice caps, based on the distribution of mapped landforms in context with field investigations of landform/sediment associations.



**Figure 1:** Location of study areas in Wales; Cadair Idris (a) and the Central Cambrian Mountains (b).

## 2. Study areas

Cadair Idris ( $52^{\circ}42'N$ ;  $3^{\circ}54'W$ ) is situated 5 km south of Dolgellau in Mid-Wales. The mountain massif consists of a high plateau ridge ca. 650–890 m a.s.l., running in west-east direction. An impressive 8 km long and up to 250 m high north-facing escarpment defines the edge of the plateau. Cadair Idris contains some of the finest assemblages of glacial erosional features that can be found in Wales.

Several glacial cirques are cut into the escarpment and the plateau, including Cwm Cau which is renowned for being one of the finest cirques in Britain. The area shows a wide range of Late Pleistocene landforms formed by glacial, periglacial and mass-movement processes, and have fascinated geomorphologists over many years. It is a key site for reconstructing the dimensions of the ice sheet at the last glacial maximum (Late Devensian) and during the following Younger Dryas (Ballyntyne2001), and has become a site of controversy regarding how thick the ice cover was during the last glacial maximum (see Ballantyne 2001; Jansson and Glasser 2005). The survival of summit plateau tors and extensive blockfields can both be explained by nunatak formation or preservation under cold-based ice.

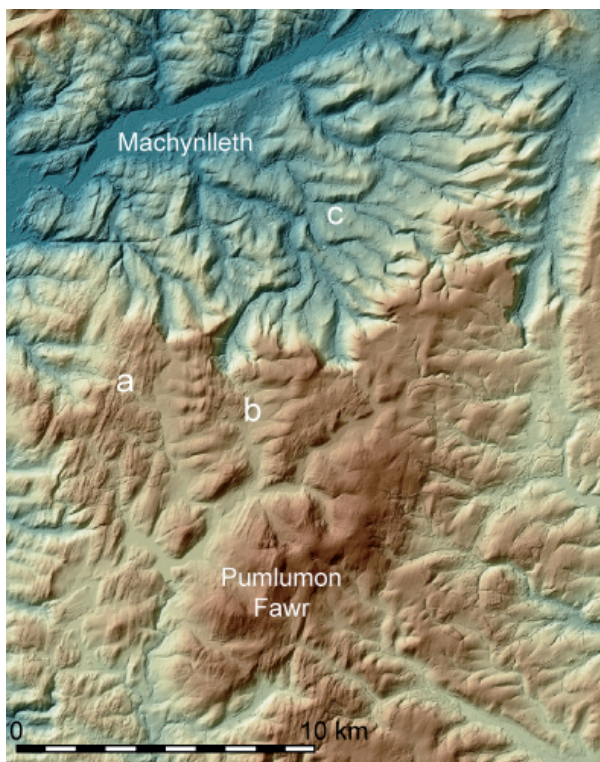
The mapped area of the Central Cambrian Mountains ( $52^{\circ}28'N$ ;  $3^{\circ}47'W$ ) consists of an upland area, ca 450–750 m a.s.l, which to the north is separated by an escarpment to a well-developed dendritic river basin. Some of the valley heads ending towards the escarpment have been occupied by cirque glaciers. The area shows otherwise little glacial imprint and has a limited spatial density of landform assemblages. This is explained by preservation under cold-based ice, due to being situated under the ice divide of the Welsh ice-cap (Jansson and Glasser 2005). Less striking than Cadair Idris, the Central Cambrian Mountains has not attracted the same attention from glaciologists. The scarcity of landforms and dated sediments has made the glacial history of the area poorly understood.

## 3. Methods

The maps of Cadair Idris and of the Central Cambrian Mountains are based on 66 and 396 colour aerial photographs (scale 1:10 000) respectively, with subsequent field controls. Interpretation of the aerial photographs was done mainly with a Hilger and Watts stereoscope. Geomorphological elements were drawn on transparent overlays, and later transferred to a georeferenced manuscript map, which was scanned and imported as a background in Adobe Illustrator.10, respectively OCAD.8, where the cartographic art work was done. Digital Elevation Models (DEMs) sourced from NEXTMap Britain has been compiled in ArcGIS.9 (ArcMap) to aid identification of palaeo-drainage pattern, glacial impact and bedrock structure. NEXTMap Britain surpasses the existing Ordnance Survey DEM in that it has a horizontal resolution of 5 m, rather than 10 m, and vertical accuracy of 1 m or less (Fig. 2).

## 4. Results and Conclusions

This is the first time the investigated areas been mapped in detail. The geomorphological maps show the spatial distribution of glacial, periglacial and postglacial features. Several new localities of ice striations, glacial meltwater



**Figure 2:** Relief-shaded Digital Surface Model (DSM) of the Central Cambrian Mountains. The high resolution data (horizontal 5 m, vertical 1 m) depicts clearly the landscape composition, such as bedrock structure (a), drift cover (b) and drainage pattern (c), and demonstrates the utility of digital elevation models in geomorphological mapping at this scale. Solar illumination is from the NW. NEXTMap Britain elevation data from Intermap Technologies in collaboration with the British Geological Survey (NERC).

channels, end moraines and areas of regolith have been found, mainly in the Central Cambrian Mountains. The new findings are promising for improving the knowledge of the glacial history and subsequent glacial reconstructions. Some of these sites are now in the process of being designated as Regionally Important Geological/Geomorphological Sites (RIGS).

Striations and ice moulded bedrock bars support the idea that the main ice sheet flowed from NE to SW across the Cadair Idris area in Late Devensian. Cirque end moraines and proglacial ramparts are inferred to have been formed during Younger Dryas, and mark the limit of local glaciers and firn fields. Glacial striations are generally found inside the limit of Younger Dryas glaciation, making it difficult to reconstruct Late Devensian ice flow. There are no conclusive results as to how thick the ice covering Cadair Idris was during last glacial maximum.

The Central Cambrian Mountains has in large part retained its preglacial drainage pattern, with V-shaped cross profiles and valley spurs typical of valleys formed by fluvial processes, indicating a cold-based ice during the better

part of Late Devensian. Other preserved landforms of pre-Late Devensian age have not been identified. Glacial striations indicate flow over the area from east to west, with a marked valley glaciation towards the end of glaciation.

For detailed geomorphological mapping, the use of the new DEMs from NEXTMap Britain is an advantageous complement in landscape analysis. However, detailed aerial photographs and subsequent fieldwork are the only way for identifying more delicate landforms, such as small moraines, patterned ground, tors and glacial striations.

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