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Glacial erosion of gneiss terrains: a re-assessment of the 'landscape of areal scouring' and implications for bed roughness below ice sheets

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Vast areas previously occupied by Pleistocene ice sheets have a rough landscape of knolls and lake-filled rock basins, the 'cnoc-and-lochan' terrain, classically interpreted as a 'landscape of areal scour'. These landscapes are typically underlain by gneiss or granitoids. The evolution of these landscapes has been variously attributed either to strong glacial erosion or to stripping of regolith from an older, deeply weathered landscape (e.g. Lidmar-Bergström 1997). Here we analyse in detail the 'cnoc-and-lochan' landscape of the NW Highlands of Scotland, its relation to bedrock structure and remnants of regolith.

We compare and contrast this landscape with:
i) an example of a gneiss terrain in a non-glacial, arid setting from Namaqualand (South Africa). This landscape comprises a rough landscape that includes knolls, rock basins and deep clefts, but lacks elongate rock-basins, whalebacks and roche moutonnées. The comparison shows that non-glacial (?mainly aeolian) erosion of gneiss can also form many elements of a 'cnoc-and-lochan' landscape.
ii) an adjacent (downstream) landscape underlain by sandstone (subjected to the same glaciations as the upstream gneiss). The sandstone landscape is very smooth and covered by locally derived till. Thus during the last glaciation we infer that little erosion of the (upstream) gneiss occurred;

It thus transpires that the rough landscape represents predominantly the old bedrock—regolith contact. This weathering front is rough as deep joints provide a highly irregular surface area for weathering to proceed. Glacial erosion (but also some other erosion processes) is simply an efficient way of stripping regolith, but is not very efficient in eroding hard, unweathered bedrock.

We conclude that glacial gneiss terrains are the result of a multistage process:
1) Long-term weathering, forming a deep, irregular weathering front largely controlled by fractures;
2) stripping of regolith during the first glaciation(s) by subglacial and possibly glaciofluvial erosion, resulting in a rough landscape with the topography conforming to the weathering front.
3) further modification of exposed bedrock by subglacial erosion; this modification is dependent on the power and thermal regime of ice-sheet flow over several glaciations (Bradwell, 2013).

Except in areas of fast ice-sheet flow (e.g. palaeo-ice streams) glacial erosion of gneiss terrain during the last glaciation(s) was low. As a result, little or no sediment was produced explaining the lack of subglacial deposition in gneiss terrains. The presence or absence of glacial till is thus strongly predicated by underlying bedrock lithology. From this study we also infer that the present-day bed of the Greenland Ice Sheet (dominated by gneiss lithologies) likely has a similar roughness as exposed, de-glaciated gneiss terrains.

Bradwell, T., 2013. EGU 2013 (this meeting)
Lidmar-Bergström, K., 1997. Earth Surface Processes and Landforms, 22, 297-306.