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Bedrock properties and glacial processes and landforms - some principles and examples

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The interpretation of glacial landforms is fundamental to the reconstruction of former ice-sheets, which in turn inform dynamic models of modern ice sheets. The leading concept of this presentation is that the morphology of (erosional) glacial landforms is controlled by:
i) glacial processes,
ii) the properties of the bedrock these processes act upon.

Indirectly, bedrock properties may also influence subglacial processes themselves. Arguably, the effects of bedrock properties on glacial processes and resultant landforms have been somewhat neglected during the last decades.

At first approximation the most relevant bedrock properties are intact rock strength and mass rock strength, for which Schmidt Hammer rebound values and joint spacing are reasonable (if non-ideal) proxies, that can be easily gathered in the field. Examples of the control or influence of bedrock properties on subglacial landforms and processes will be presented:

• In NW Scotland, a palaeo-ice stream flowed at right angles over a sandstone/quartzite contact. The sandstone is relatively soft but thick-bedded with a wide joint spacing. Erosional bedforms suggest a high proportion of abrasion over plucking. The quartzite is hard but thin-bedded with narrow joint spacing. Erosional landforms are angular with abundant plucked faces, suggesting a high proportion of plucking over abrasion. Hardness and joint spacing thus exert a strong control on the dominantly operating subglacial erosional process and the resultant landforms [1, 2].

• Again in NW Scotland it is observed that in the transition from gneiss to sandstone, gneiss is barren with numerous rock basins (cnoc-an-lochan landscape), whilst the sandstone shows near-continuous till cover, composed of sandstone debris. This suggests that the gneiss/sandstone properties control rock basin formation (implication: lake abundance is not a reliable proxy for intensity of glacial erosion) but also the boundary between erosion and deposition beneath an ice sheet (implication: no conclusions can be drawn with respect to the thermal regime of an ice sheet). Similar transitions may occur in Scandinavia and Canada.

• In valley-glaciation settings, debris-covered glaciers are known to respond differently to climatic variations than debris-free glaciers, e.g. the Miage Glacier in the Mont Blanc area [3]. But what causes some glaciers to be debris covered, and others not? Much of the Mont Blanc Massif comprises massive granite with high intact rock strength, whilst the Miage Glacier is surrounded by schistose gneisses with a lower intact rock strength, resulting in more frequent supraglacial rock falls.

These examples show that bedrock properties can exert an important control on erosional as well as depositional processes in subglacial/proglacial environments. The uncertainty of inferences on the palaeo-glaciology or palaeo-climate of a glacial system based upon geomorphology can thus be decreased if the influence of bedrock properties is taken into account.

[1] Krabbendam & Glasser, 2011. Geomorphology, 130, 374-383
[2] Duhnforth et al. 2010. Geology, 38, 423-426.
[3] Thomson et al. 2000. IAHS Pub. v. 264, 219-225.