Geophysical Research Abstracts,
Vol. 11, EGU2009-5412-1, 2009
EGU General Assembly 2009

Bedrock structure and the interpretation of palaeo ice stream footprints: examples from the Pleistocene British Ice Sheet

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To model past and future behaviour of ice sheets, a good understanding of both modern and ancient ice streams is required. The study of present-day ice streams provides detailed data of short-term dynamic changes, whilst the study of Pleistocene palaeo-ice streams can provide crucial constraints on the longer-term evolution of ice sheets. To date, palaeo-ice streams, such as the classical Dubawnt Lake palaeo-ice stream of the former Laurentide Ice Sheet, have been recognised largely on the basis of extremely elongate drumlins and megascale glacial lineations; all soft-sediment features. Whilst it appears that topographically unconstrained ice streams (eg. within the West Antarctic Ice Sheet) are generally underlain by deformable till, topographically constrained ice streams such as Jakobshavn Isbrae do not require deformable sediment and may occur on a bedrock-dominated bed.

Analysis of DEM data and geomorphology and structural geology fieldwork in Northern Scotland and Northern England has shown the occurrence of highly streamlined bedforms in bedrock of the former base of topographically controlled palaeo-ice streams, which drained parts of the British Ice Sheet. The bedforms are predominantly bedrock megagrooves with asymmetric cross-profiles. In the Ullapool tributary of the Minch palaeo ice stream, bedrock megagrooves form the dominant evidence for ice streaming. The megagrooves are typically 5-15 m deep, 10-30 m wide and 500 – 3000 m long. Spacing of megagrooves is typically 100 – 200 m.

In both study areas, the bedrock is strongly anisotropic, either consisting of thin-bedded strata or strongly foliated metasedimentary rocks, with the strata or foliation having a gentle dip. Megagrooves are best developed where the strike of the anisotropy is sub-parallel (within 10 – 20°) with palaeo ice flow. The bedrock in both areas has a well-developed, relatively densely spaced (< 1m), conjugate joint system.

We suggest that asymmetric megagrooves are formed by "lateral plucking", facilitated by the combination of strong bedding/foliation and the joint pattern. Glacial erosion was laterally more effective than vertically; so that stepped faces subparallel to palaeo ice flow are enhanced rather that destroyed.

We propose that:
a) Lateral plucking is an effective mechanism to produce streamlined bedrock bedforms by fast ice flow, providing the bedrock and bedrock structure are suitable;
b) some topographically controlled palaeo-ice stream beds are dominated by bedrock rather than soft-sediment;
c) the recognition of palaeo-ice streams may be dependent on the type of bedrock and the orientation of bedrock structure with respect to palaeo ice flow;
d) palaeo-ice stream footprints may have been underestimated in formerly glaciated areas.