Glacial landforms in a hard bedrock terrain, Melville Bay, northwestern Greenland

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Glaciated landscapes in gneissose or granitic bedrock often show a scoured ‘hilly relief’ (Bonow et al. 2006) or ‘knock-and-lochan’ morphology (Linton 1963), characterized by a highly fractured landscape with strong relief of knolls and basins. This topography closely follows old deep-weathering fronts from previous subaerial exposure, and was probably formed through a multistage process including deep weathering, glacial erosion and stripping of saprolites, followed by further glacial modification (Krabbendam & Bradwell 2014). Multibeam-bathymetric data and high-resolution onshore digital elevation models (DEM) from southern Melville Bay, NW Greenland, show similar glacially modified knock-and-lochan landscapes from the inner shelf and nearby coast.

Description

Over a bathymetric range of 150–400 m on the inner Melville Bay shelf, c. 30 km from the West Greenland coast, the seafloor shows a rugose, bedrock-dominated landscape with limited sediment cover (Fig. 1a). The bedrock onshore, to the east of the study area, consists of Precambrian metaturbidites and orthogneisses (Kokfelt et al. 2013). The submarine landscape is dominated by criss-crossing incisions, numerous knolls, depressions, angular junctions and steep scarps. Minor landforms include U-shaped troughs, streamlined features and roche moutonée-type features often with stoss- and lee-side forms that have a clear dominant trend towards the NW (Fig. 1d). Iceberg ploughmarks occur at c. 270 m depth in relatively flat areas (Fig. 1b). A trough, too deep to be surveyed using the high-frequency multibeam system, bisects the survey area into a northern and a southern part. While the two areas show a similar ice-scoured landscape, the northern part has a more varied topography (50–500 m bsl), several fault escarpments (Fig. 1c), semi-circular basins, streamlined features and tall knolls. The southern area shows weaker relief (200–500 m bsl) and is characterized by an irregular fracture pattern, stoss- and lee-forms and distinct U-shaped troughs (Fig. 1a, f).

Multibeam data were compared with a 10 m resolution onshore satellite-derived DEM (Noh & Howat 2015) from the nearest available location, c. 100 km SE of our survey area (black box, Fig. 1g). The DEM exhibits a more pronounced relief with maximum elevations of about 1000 m and similar bedrock-dominated topography with tall knolls and deep basins, U-shaped troughs and streamlined features (Fig. 1d).

Interpretation

The dominant observed pattern appears to be governed by bedrock structures, with minor modification by glacial activity. The seafloor shows knolls, narrow troughs, small basins, fractures, steep scarps and curvilinear ridges. These features are characteristic of bedrock in weathered, folded and faulted metamorphic terrain such as those of the SW Greenland coast (Bonow et al. 2006) and NW Scotland (Krabbendam & Bradwell 2014). Some glacial modification of the bedrock terrain is indicated by U-shaped troughs, moutonée-type landforms, stoss-and-lee forms and streamlined features. The lack of sediment on the inner shelf is probably due to limited sediment supply owing to long seasons of sea-ice cover combined with a capacity for sediment erosion and removal by the northward-flowing West Greenland Current (Curry et al. 2011; Freire et al. 2015).

We suggest that the seafloor morphology off NW Greenland is the result of deep weathering and subsequent stripping of the saprolites by glacial erosion, akin to NW Scotland (Krabbendam & Bradwell 2014). Because the northern and southern areas show similar signs of glacial erosion, major differences in weathering or abrasion capacity are unlikely. The morphological differences in the two areas probably reflect variations in bedrock lithology. Analysis of SETSM and geological data (Kokfelt et al. 2013) from the adjacent coast reveals that the strong relief with distinct knolls mainly occupies metaturbidite terrain, as in our northern area; whereas the more subdued relief with roche moutonée forms and criss-crossing incisions occurs in orthogneiss, as in our southern area (Freire et al. 2015). The steep fault escarpments, only found in the northern area, are consistent with normal faulting towards central Baffin Bay, and are probably linked to the opening of the Labrador Sea during early Cretaceous time.

During the Last Glacial Maximum, the NW Greenland Ice Sheet extended at least to the mid-shelf, and several ice-stream troughs cross-cut the shelf in a SW direction (Funder et al. 2011). One of these is the Melville Bay trough NW of the offshore study site. In contrast, the directions of the interpreted glacial landforms in our data indicates that ice flowed northwestward (Fig. 1a, d, h) towards the large Melville Bay trough, rather than directly westward towards the shelf edge. Together with the presence of erosional bedrock landforms shaped by a dynamic ice-flow environment (i.e. streamlined features, depressions and knolls, angular junctions), this leads to the conclusion that the offshore study area acted as a tributary or onset region for the major palaeo-ice stream that formed the present-day Melville Bay trough.

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Fig. 1. Multibeam bathymetry and land DEM from Melville Bay. Acquisition system Kongsberg EM 2040. Frequency 200–400 kHz. Grid-cell size 5 m. (a) Multibeam bathymetry showing a bedrock-dominated landscape with glacial imprint. (b) Multibeam bathymetry acquired with an AUV showing iceberg ploughmarks at 270 m depth. Acquisition system Geoswath interferometric sonar. Frequency 250 kHz. Grid-cell size 1 m. (c) Scarp profile (VE x 2). (d) Rose diagram of azimuths of 186 glacially moulded features indicating ice movement towards 300° (NW). (e) Onshore DEM from satellite (SETSM) data (located in (g), black box). Grid-cell size 10 m. Light blue area, Qeqertarsuup Sermia outlet glacier (QS). (f) 3D-perspective view (red lines in (a)), showing the steep fault escarpments in the north, and U-shaped troughs and moutoné-type forms in the south. (g) Location of study area (red box) and onshore comparison area (black box); map from IBCAO v.3.0. (h) Detail from (a) showing streamlined features, moutoné forms and stoss-and-lee forms, indicating glacial movement towards the NW (white arrow).