



Subglacial lakes and landforms beneath the Scandinavian ice sheet – examples from Norway

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At many places in Scandinavia, geomorphological evidence tells about catastrophic meltwater floods from the last Scandinavian ice sheet. Some of these landforms, like the Jutulhogget canyon in southern Norway, can be explained by drainage from ice-dammed lakes. However, meltwater floods from water stored in subglacial lakes seem to be even more common. At some locations, canyons with depth up to a hundred meters have been formed by such meltwater outbursts, and coarse stone material with diameters one meter or more have been transported by the flood water. Here we concentrate on examples from Norway, especially southern Norway. In southern Norway, traces of subglacial lakes are found near the culmination areas of the last ice sheet, like at the Hardangervidda mountain plateau, in the areas east of the Jotunheimen mountains, and in the areas near lake Femund in eastern southern Norway. In all these areas, subglacial sediments and landforms are found almost everywhere. Drumlin fields or surfaces dominated by an assemblage of streamlined features (drumlins, crag and tails, flutes or megaflutes) are common. This is also the distribution area of Rogen moraines (ribbed moraines). The type locality of Rogen moraines, the lake Rogen near the border between Norway and Sweden, are situated not far from an area (lake Femund) with strong evidence for a large subglacial lake. The subglacial moraine forms have a distinct local distribution within this region. Rogen moraines are found in lower, concave parts of the terrain, while the streamlined drumlinoide forms are found on flat or convex surfaces.

We suggest that all subglacial moraines in these areas were formed beneath a wet-based glacier, in subglacial conditions where all cavities were filled by water. Rogen moraines are located to topographic positions occupied by shallow, subglacial lakes, and the moraine ridges were formed by ice movement across these shallow lakes. The

sediments were then deposited or redistributed in ridges transverse to the ice movement direction, even if the exact mechanism of ridge formation in such environment are still not clear. In areas where the ice moved in contact with the terrain surface, different types of streamlined, drumlinoide features were formed. Friction against the bed was probably rather low due to the water pressure, and there is no evidence of extensive glacial erosion. In deeper, subglacial lakes or in areas just below the ice divide, hummocky moraines without preferred orientation are found. Rogen moraines, drumlins and transitional forms between these two types of moraines were all formed by ice movement at the bottom of a thick ice sheet. In these culmination areas of the Scandinavian ice sheet, the distinct distribution pattern of different moraine types are related to local variations in water pressure or volume of subglacial water.