



## **Estimating depth and spatial distribution of Holocene permafrost in Norway**

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Following the last glaciation, cryogenic processes related to valley and cirque glaciers, permafrost and seasonal frost have dominated Norwegian landscape development in high-mountain areas. This is evident by different landscape and landform features, like rock glaciers, block fields, palsas, ice-wedge polygons and ice-cored moraines. A recently developed inventory of permafrost-related landforms clearly demonstrates a spatial pattern which is attributed to different climate conditions during Holocene.

While the Holocene glacial history is well established, the development of permafrost through Holocene is poorly investigated. Important climatic shifts such as the warmer Atlanticum and the cooler Little Ice Age are of special interest concerning the distribution of permafrost. Here, we hypothesise that there must exist a zonation for the age of permafrost in the mountains of Scandinavia, which might again be related to geomorphological process patterns and landform zonation. We can expect a zone where permafrost have prevailed during the whole Holocene and possibly before, depending on cold-based glacier conditions during the late Weichselian glaciation. Another permafrost zone might have survived the Atlanticum below talliks, while in a lower zone permafrost is a late Holocene feature. Below this zone, permafrost might never have existed during Holocene.

To test this hypothesis we first established Holocene temperature curves for both northern and southern Norway by compiling existing proxy data. The shape and relative values of the constructed temperature curves of Norway were compared to temperature data from the ice core projects in Greenland, and found satisfactory for the objective of this study. Subsequently, we used these temperature curves to drive a 1D heat flow model for selected sites in which ground temperature monitoring provide data for model calibration during present conditions. Such boreholes exist in mountain areas of both southern and northern Norway, established through the IPY projects 'Thermal State of Permafrost – Norway (TSP-Norway)' and 'CRYOLINK - Permafrost and seasonal frost in Southern Norway'. In a final step maps of hypothetical permafrost ages were derived using a spatial permafrost equilibrium model, and compared to permafrost-related landform inventories. The results from this study (1) demonstrate an altitudinal pattern of permafrost appearance during the Holocene, (2) indicate maximum permafrost depths and (3) spatial extend reached during the Late Holocene period and the Little Ice Age, in accordance to the glacier variation during this time period.