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## Helagsglaciären - a storyteller of Holocene history

Helagsglaciären in Jämtland is Sweden's southernmost glacier, which makes it particularly sensitive to climate changes. However, Sweden has a poor history of mapping and dating moraine sequences of mountain glaciers, unlike in neighbouring Norway. This study aimed to begin to fill this gap.

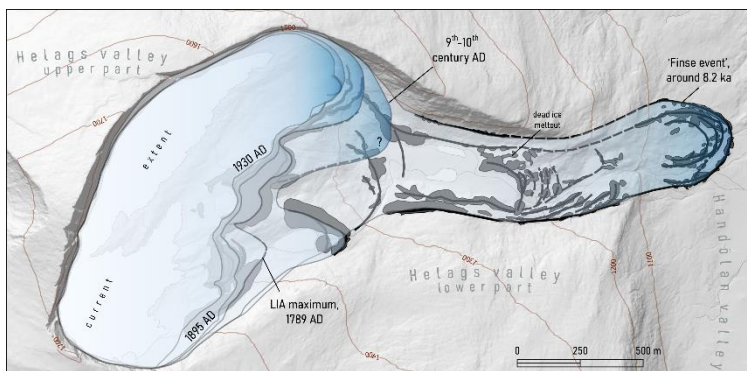
Four techniques were combined to find out about Helagsglaciären's dynamics, chronology and relationship with climate. Firstly, the entire Helags valley geomorphology was mapped remotely and then validated in the field up to the reaches of the outermost moraine. Secondly, three outcrops were dug in different moraines and their sediments logged. These two techniques served to infer about the glacier's past dynamics and thermal regime. Thirdly, lichen diameters were measured on 21 moraines spanning the entire valley, and related to a local diameter-age calibration curve to calculate the age of deposition of the moraines. Lastly, Equilibrium Line Altitudes (ELA) of Helagsglaciären were calculated for six time periods known from lichenometry in order to reconstruct palaeotemperature and palaeoprecipitation at the glacier's site.

The Helags valley is occupied by extensive glacial sediments much beyond the current extent. This indicates prominent past advances of Helagsglaciären throughout the Holocene. Moraines deposited in 1930, 1908, around 1870s, 1840s and 1790s AD (Little Ice Age maximum) occupy the Helags cirque. Slightly further are moraines dated to 8<sup>th</sup>-12<sup>th</sup> century AD, which is the upper limit of lichenometry. All these mentioned deposits indicated an active, warm-based temperate glacier. Unfortunately, lichenometry could not accurately assign ages to sediments in the lower parts of the valley which recorded more of a polythermal regime. It was decided that their likely age could be inferred from comparison of palaeoclimatic data from Helags valley with other climatic records from Scandinavia.

### Helagsglaciären contra other environmental archives

The very cold and wet climate reconstructed for the outermost sediments in Helags valley corresponds well with multiple studies describing the 'Finse event' around 8.2 ka. Polythermal nature of the palaeoglacier also points to the early Holocene age because later the climate was too warm to allow such a thermal regime and extent of glaciation. As such, this age was proposed here. Thanks to the climatic comparison with other studies, the 8<sup>th</sup>-12<sup>th</sup> centuries age was narrowed to the 9<sup>th</sup>-10<sup>th</sup> centuries AD. The reconstructed LIA climate also agreed well with other known proxies. At last, the complete interpretation of Helags valley sediments spans most of the Holocene (see figure).

What does this imply for the palaeoglaciological research? Helagsglaciären was the first glacier in Sweden where a complete Holocene reconstruction from moraine sediments has been attempted. It showed that a glacier's thermal regime can switch from a polythermal to a temperate one, in contrast to changes observed on modern glaciers in High Arctic. Helagsglaciären's behaviour is heavily influenced by topography. Despite that, it correlated well with other palaeoclimatic proxies from Scandinavia. This warrants more attention paid to cirque glaciers when reconstructing palaeoclimate, although only further studies of groups of neighbouring glaciers can confirm how reliable this conclusion is.



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