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Formation and age of tors and other weathering residuals in northeastern Sweden

C. Hättestrand (1), A. P. Stroeven (1), D. Fabel (2), O. Fredin (3) and L. Johansson (1)

(1) Department of Physical Geography and Quaternary Geology, Stockholm University, Sweden, (2) Department of Geographical and Earth Sciences, University of Glasgow, UK, (3) Geological Survey of Norway, Trondheim, Norway (clas.hattestrand@natgeo.su.se / Fax: +46-8-164818 / Phone: +46-8-164952)

The presence of tors in areas of former glaciation has been used to infer frozen bed conditions of ice sheets. This is because they are delicate features, often with loosely stacked and perched boulders that would not survive even short periods of wet-based erosional glacial conditions. Therefore, where tors have apparent terrestrial cosmogenic nuclide (TCN) exposure ages with inheritance or where they have erratics on their surfaces, they are considered reliable indicators of landform-protective subglacial conditions. However, understanding the formational history of tors is of fundamental importance for the subsequent interpretation of subglacial protective conditions. In this study we have examined the detailed surface and subsurface morphologies and apparent TCN exposure ages of tor summit surfaces in a relict landscape area of northern Sweden.

The Parkajoki area in northeastern Sweden is situated near the central area of Fennoscandian ice sheet glaciation. Despite its location, the area is dominated by well-developed tors, boulder fields, and boulder depressions, and is known to have a widespread occurrence of saprolites beneath till sheets. Unlike most other areas with tors in glaciated regions, the Parkajoki area is uniquely situated in the lowlands at 150-400 m a.s.l. This relict landscape is furthermore surrounded by drumlins, ribbed moraine, and eskers of varying age, but at similar elevation. The Parkajoki area has therefore been interpreted to have been a frozen bed island in an otherwise thawed

glacier bed during repeated glaciations.

The surface morphology of the Parkajoki tor is characterized by flat upper surfaces, vertical cliff faces, and closely spaced horizontal joints that are weathered and have rounded edges, giving it an appearance of a stack of pancakes. The subsurface tor morphology visible in excavated trenches in the till sheet that covers the flanks of the tors reveals largely unweathered bedrock surfaces, mostly characterized by sharp edges, although pockets of saprolite are present at the bedrock surface. Schmidt-hammer tests confirmed that subaerial surfaces were substantially more weathered than subsurface bedrock faces.

Tor summit surface ^{10}Be and ^{26}Al data yield apparent exposure ages ranging from 37 to 78 ka. These ages are consistent with the geomorphological interpretation that these features are relict landforms that have survived glaciation with little or no erosion. In addition, mean cosmogenic ^{26}Al/^{10}Be concentration ratios from two of the sites indicate a minimum total history exceeding 600 ka (mid-Quaternary) and a maximum erosion rate of 1.6 m Ma^{-1}. Boulder fields and boulder depressions in the area have lower exposure ages, ranging from 17 ka to 38 ka, and are interpreted to be younger periglacial features formed by frost shattering and frost heave during interstadials.

Because of the general occurrence of saprolites in the area and the presence of saprolites pockets beneath the till close to the tors, we interpret the location of the tors to be controlled by deep weathering and stripping. At some stage preceding the mid-Quaternary glacial erosion and/or periglacial frost weathering are likely to have caused an angular appearance of the bedrock surface and the deposition of one or several till sheets. Subsequently, subaerial weathering has been the primary agent for sculpturing the present surface morphology of the tors, while subsurface parts have remained unweathered.