Deep weathering patterns on the Fennoscandian shield in northern Finland

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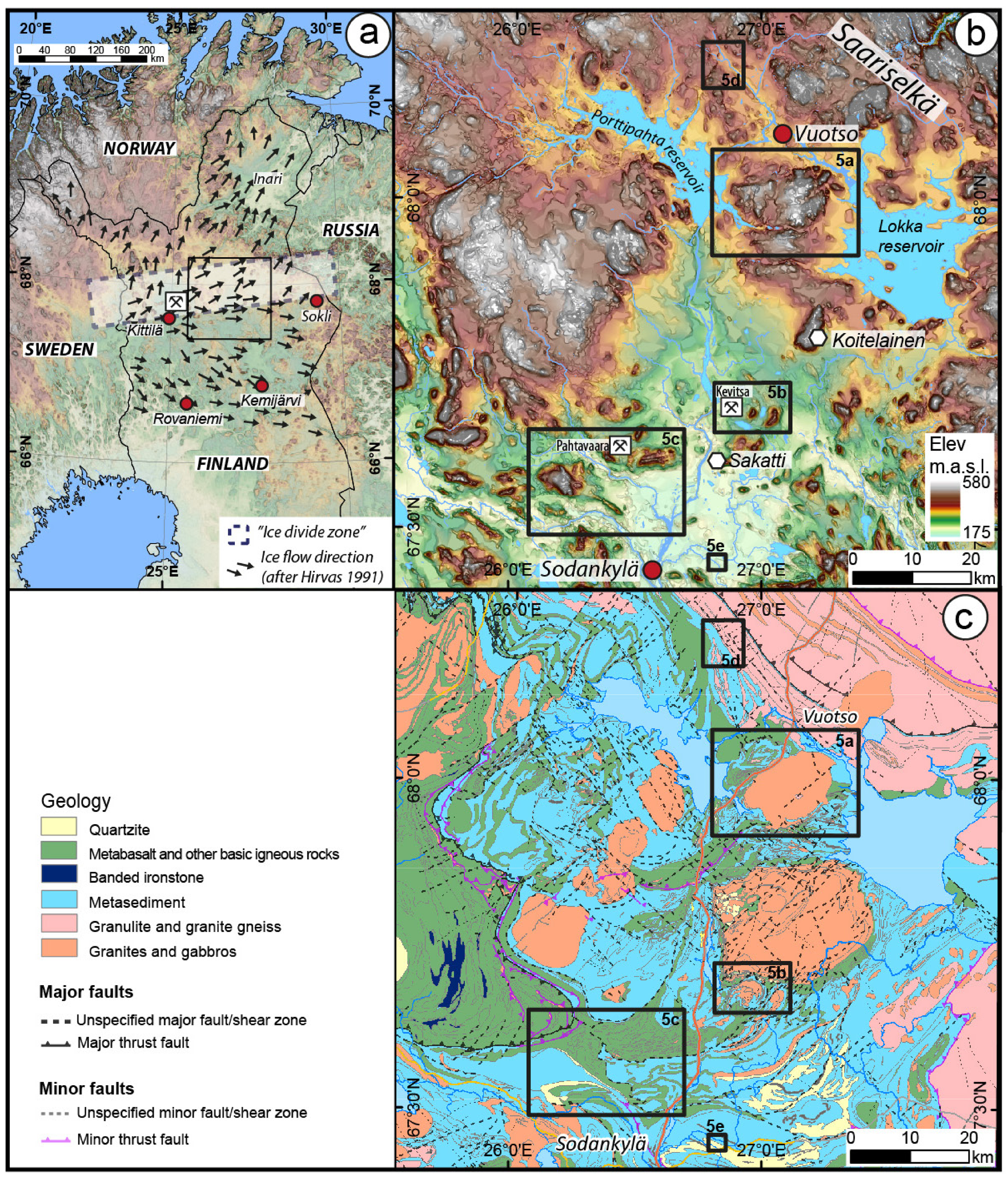
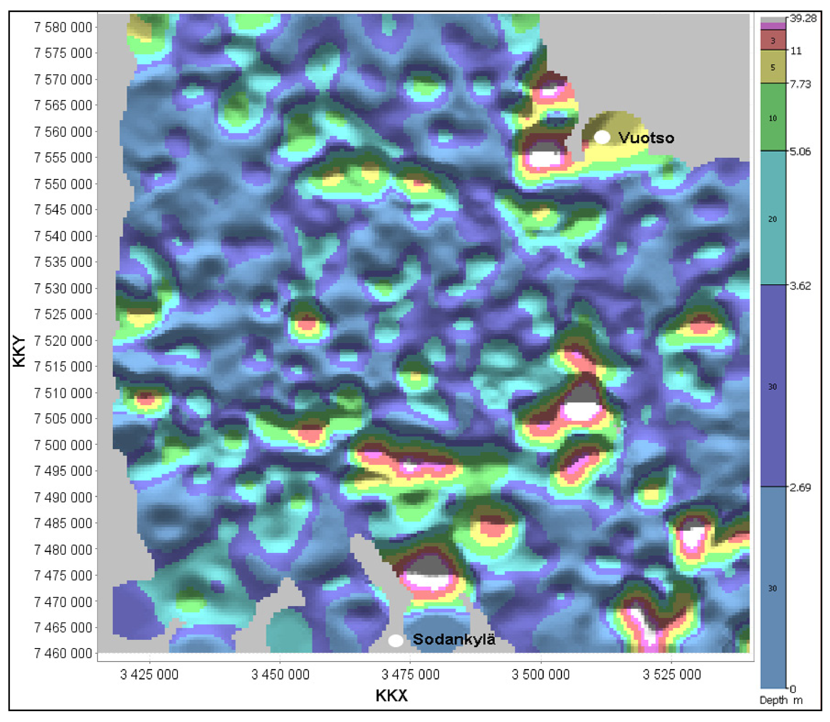
Global cooling in the Late Cenozoic led at 3.2-2.6 Ma to the first of many advances by large ice sheets onto the shield lowlands of the Northern Hemisphere. Erosion by ice sheets progressively removed thick, deformable and permeable pre-glacial regolith from shield surfaces to expose rigid and impermeable rock beds. This fundamental change in substrate has been linked to marked changes in ice sheet dynamics and extent through the Late Pliocene and Pleistocene. However, in northern Finland, a deeply weathered Late Neogene landscape is exceptionally preserved in the ice sheet divide zone. The preservation of extensive and deep Neogene weathering requires that cold-based glaciers developed in the same areas repeatedly and throughout the glaciation history.

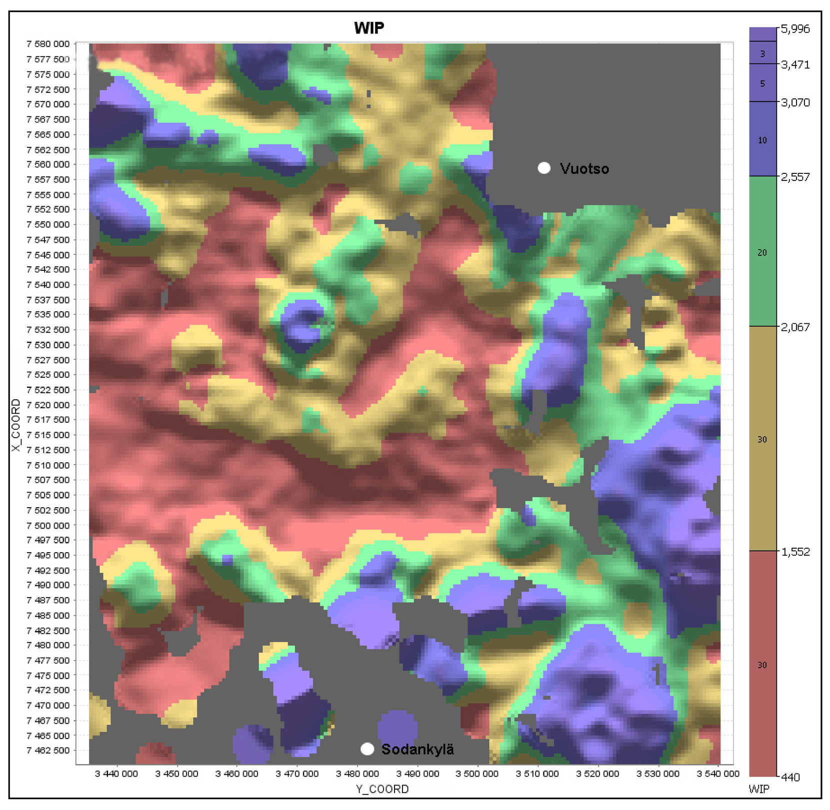
The nature of the regolith that existed on the shields of the Northern Hemisphere at the onset of ice sheet glaciation is poorly known. Even in Finland, where deep weathering is known to exist extensively beneath till, the regional distribution and geochemistry of these weathering mantles has not been analysed systematically. Using depth and geochemical attribute data of a large percussion drilling dataset of the Geological Survey of Finland, we explored the weathering patterns in this unique area. We used a variant of the Weathering Index of Parker (WIP) as a proxy to assess the intensity of weathering (Hall et al. 2015).



Location, relief and geology. (A) Location, (B) Relief, (C) Geology and structure.



Regional weathering distribution and depth.

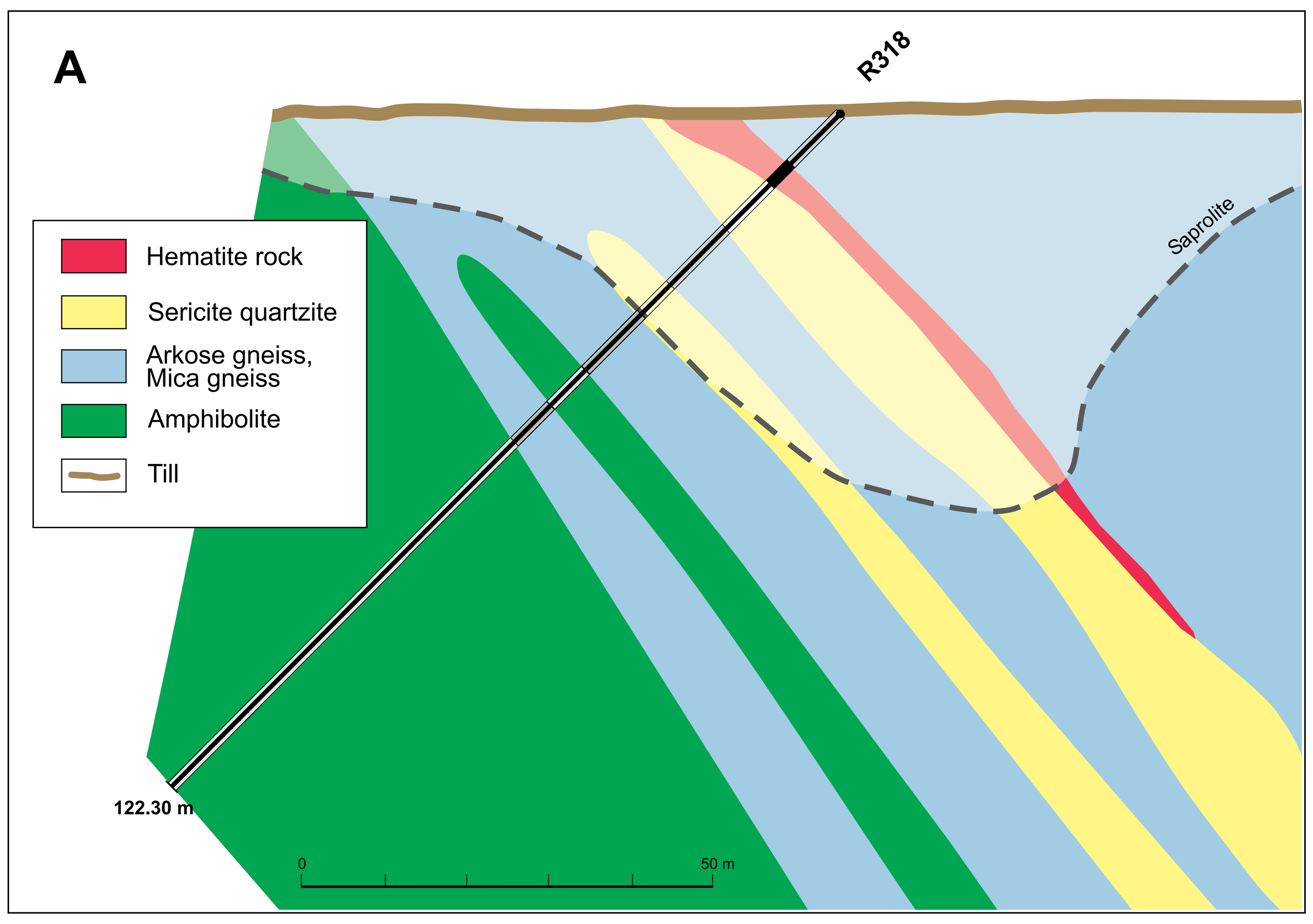


Regional patterns in weathering intensity.

Results

The research shows that the topography of central Lapland is closely linked to its geology and structure. All these factors influence weathering patterns. Before the onset of glaciation, resistant granulite, granite, gabbro, metabasalt and quartzite hills had many fresh rock outcrops, including tors, and areas with thin (<5 m) grusses. Plains developed across less resistant biotite gneisses, greenstones and belts of alternating rock types were mainly weathered to thick (10-20 m) grusses with WIPfines values above 3000 and 4000. Beneath valley floors developed along mineralised shear and fracture zones, weathering penetrated locally to depths of >50 m and included intensely weathered kaolinitic clays with WIPfines values below 1000.

Three-part clay-gruss-saprock profiles occurred only in limited areas. In those cases, the weathering profiles reached up to 100 m in depth. Two-part gruss-saprock profiles are widespread, with saprock thicknesses of >10 m. However, incipient weathering and supergene mineralisation also extend to depths of >100 m in mineralised fracture zones.



Example of deep weathering in Mäkärä at the Vuotso region. (A) Borehole R318 in kaolin-rich saprolite and (B) Surface trench showing kaolinitic saprolite beneath thin till. Photo P. Sarala.

Conclusions

We confirm that glacial erosion has been very limited (<20 m) in northern Finland and has been widely restricted to the partial stripping of saprolith. The Fennoscandian Ice Sheet in this ice-divide zone remained cold-based and unerosive throughout the Pleistocene. The large-scale shield geomorphology developed before glaciation and is a product of differential weathering and erosion acting on diverse rock types and structures through the Neogene. In northern Finland, the shield topography comprised broad plains and valleys with isolated hills and hill masses, with a relative relief of several hundred metres. Weathered rock was restricted in its distribution and thickness and provided diverse bed materials for ice sheets, including rock, broken saprock, permeable gruss, and linear zones of impermeable clay, with multiple discontinuities. Glacial erosion and local glacial transport led to widespread incorporation of this saprolith material into tills. Recognition of this influence is important for mineral exploration.

Reference

Hall, A., Sarala, P. & Ebert, K. 2015. Late Cenozoic deep weathering patterns on the Fennoscandian shield in northern Finland: a window on ice sheet bed conditions at the onset of Northern Hemisphere glaciation. Geomorphology 246, 472-488.

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