

## **Plant growth on debris covered glacier surfaces - ecology, vegetation patterns and implications for debris mantled glaciers serving as cold and warm stage plant refugia in the past**

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As stated at the International Conference on Debris-Covered Glaciers in 2000, “debris-covered glaciers comprise a significant fraction of the global population of glaciers...” Given a minimum of debris thickness and sufficient stability, these surfaces host surprisingly diverse plant assemblages, both floristically and structurally. Observations of plant growth on glacier surfaces are reported from around the world – including mature forests with trees more than 50cm in diameter.

Debris covered glacier surfaces are mobile habitats for plants, which migrate downhill with glacier movement, but are able to spread upward with strong anabatic valley winds. Plant growth is possible even on a very shallow debris cover. Depending on site conditions, floristic composition and structure of vegetation on debris covered glaciers represent a mosaic of environments, including subnival pioneer communities, glacier foreland early- to late-successional stages, and morainal locations. The taxa involved display a wide spectrum of adaptations to habitat conditions with particular migration and dispersal strategies. With a shallow debris cover, alpine/subnival taxa can grow considerably below their usual altitudinal niche due to the cooler subsurface soil temperatures. In contrast, a greater thickness of debris cover allows even thermophilous plants of lower elevations to grow on glacier surfaces.

Employing the principle of actualism, debris covered glaciers provided important and previously undocumented refugia for plants during the Pleistocene cold stages from which alpine and arctic plant species were able to re-establish and spread in post-glacial time. This assumption is complementary to the two competing ideas to explain the fate of alpine and/or arctic taxa during the Pleistocene, the nunatak hypothesis (i.e. in-situ survival of plants on unglaciated summits) and tabula rasa theory (i.e. displacement of plants and subsequent remigration). Vice versa debris covered glaciers might have served as refugia for cryophilic plants during Holocene warm stages.