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Controls of sediment transfers, sedimentary budgets and relief development in cold environments: Results from four catchment systems in Iceland, Swedish Lapland and Finnish Lapland

A. A. Beylich
Geological Survey of Norway (NGU), NO-7491 Trondheim, Norway (achim.beylich@ngu.no)

By the combined, longer-term and quantitative recording of relevant denudative slope processes and stream work in four selected catchment systems in sub-arctic oceanic Eastern Iceland (Hrafndalur and Austdalur), arctic-oceanic Swedish Lapland (Latnjavagge) and sub-arctic oceanic Finnish Lapland (Kidisjoki), information on the absolute and relative importance of the different denudative processes is collected. Direct comparison of the four catchment geo-systems (the catchment sizes range from 7 km2 to 23 km2) allows conclusions on major controls of sediment transfers, sedimentary budgets and relief development in theses cold climate environments.

To allow direct comparison of the different processes, all mass transfers are calculated as tonnes multiplied by meter per year, i.e. as the product of the annually transferred mass and the corresponding transport distance. Ranking the different processes according to their annual mass transfers shows that stream work dominates over slope denudation. For Hrafndalur (Eastern Iceland) the following order of denudative processes is found after nine years of process studies (2001 - 2010): (1) Fluvial suspended sediment plus bedload transport, (2) Fluvial solute transport, (3) Rock falls plus boulder falls, (4) Chemical slope denudation, (5) Mechanical fluvial slope denudation (slope wash), (6) Creep processes, (7) Avalanches, (8) Debris flows, (9) Translation slides, (10) Deflation. Compared to that, in Austdalur the following ranking is given after fourten years of process studies (1996 - 2010): (1) Fluvial suspended sediment plus bedload transport, (2) Fluvial solute transport, (3) Mechanical fluvial slope denudation (slope wash), (4) Chemical slope denudation, (5) Avalanches, (6) Rock falls plus boulder falls, (7) Creep processes, (8) Debris flows, (9) Deflation, (10) Translation slides. In the Latnjavagge catchment (Swedish Lapland) the ranking is (eleven-years period of studies, 1999 - 2010): (1) Fluvial solute transport, (2) Fluvial suspended sediment plus bedload transport, (3) Rock falls plus boulder falls, (4) Chemical slope denudation, (5) Mechanical fluvial slope denudation (slope wash), (6) Avalanches, (7) Creep processes and solifluction, (8) Slush flows, (9) Debris flows, (10) Translation slides, (11) Deflation. In Kidisjoki (Finnish Lapland) the order of processes, as determined after a nine-years period (2001 - 2010) of geomorphic process studies, is: (1) Fluvial solute transport, (2) Chemical slope denudation, (3) Fluvial suspended sediment plus bedload transport, (4) Mechanical fluvial slope denudation, (5) Creep processes, (6) Avalanches and slush flows, (7) Debris flows and slides, (8) Rock and boulder falls, (9) Deflation.

As a result, in all four selected cold climate study areas the intensity of contemporary denudative processes and mass transfers is altogether rather low, which is in opposition to the earlier postulated oppinion of a generally high intensity of geomorphic processes in cold climate environments.

A direct comparison of the annual mass transfers summarises that there are differences between process intensities and the relative importance of different denudative processes within the four study areas. The major controls of these detected differences are: (i) Climate: The higher annual precipitation along with the larger number of extreme rainfall events and the higher frequency of snowmelt and rainfall generated peak runoff events in Eastern Iceland as compared to Swedish Lapland and Finnish Lapland lead to higher mass transfers, (ii) Lithology: The low resistance of rhyolites in Hrafndalur causes especially high weathering rates and connected mass transfers in this catchment. Due to the lower resistance of the rhyolites as compared to the basalts found in Austdalur Postglacial modification of the glacially formed relief is clearly further advanced in Hrafndalur as compared to Austdalur, (iii) Relief: The greater steepness of the Icelandic catchments leads to higher mass transfers here as compared to Latnjavagge and Kidisjoki, (iv) Vegetation cover: The significant disturbance of the vegetation cover by human impacts in Easter Iceland causes higher mass transfers (slope wash) whereas restricted sediment availability is a main reason for lower mass transfers in Swedish Lapland and Finnish Lapland.

The applied catchment-based approach seems to be effective for analysing sediment budgets and trends of Postglacial relief development in selected study areas with given environmental settings. Direct comparison of investigated catchments will improve possibilities to model relief development as well as possible effects of projected climate change in cold climate environments.