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Soil production rates on silicate parent material in high-mountains: different approaches – different results?

Markus Egli (1), Dennis Dahms (2), and Kevin Norton (3)

(1) Deptartment of Geography, University of Zürich, Switzerland (markus.egli@geo.uzh.ch), (2) Department of Geography, University of Northern Iowa, Cedar Falls, USA, (3) School of Geography, Environment and Earth Sciences (SGEES), Victoria University of Wellington, New Zealand

High-mountain soils develop in particularly sensitive environments. Consequently, deciphering and predicting what drives the rates of soil formation in such environments is a major challenge. In terms of soil production from chemical weathering, the predominating perception for high-mountain soils and cold environments often is that the chemical weathering 'portion' of soil development is temperature-inhibited, often to the point of non-occurrence. Several concepts exist to determine long-term rates of soil formation and development. We present three different approaches: (1) quantification of soil formation from minimally eroded soils of known age using chronosequences (known surface age and soil thickness - SAST), (2) determination of soil residence times (SRT) and production rates through chemical weathering using (un)stable isotopes (e.g. ^{230}Th / ^{234}U activity ratios), and (3) a steady state approach using cosmogenic isotopes (e.g. ^{10}Be).

Data form different climate zones, and particularly from high-mountains (alpine environment), were compared. The SAST and steady state approach gave quite similar results for alpine environments (European Alps and the Wind River Range (Rocky Mountains USA)). Soil formation rates in mountain areas (but having a temperate climate) using the SRT approach, did not differ greatly from the SAST and Steady State approaches. Independent of the chosen approach, the results seem moderately comparable. Soil formation rates in high-mountain areas (alpine climate) ranged from very low to extremely high values and showed a clear decreasing tendency with time. Very young soils have up to 3 – 4 orders of magnitude higher rates of development than old soils (10^5 to 10^6 years). This is due to the fact that weathering is kinetically limited in regions having young surfaces and supply limited on old surfaces.

Soil production rates cannot be infinitely high. Consequently, a speed limit must exist. In the literature, this limit has been set at about 320 to 450 t km^{-2} yr^{-1}. Our results show, however, that in alpine areas soil formation easily reaches rates of up to 1000 – 3000 t km^{-2} yr^{-1} using the SAST approach. These data are consistent with previous studies in mountain regions demonstrating that soils continue to develop with time, even under continuous seasonal snowpack and, thus, that the concept of 'temperature-controlled' soil development (soil-forming intervals) is spurious.