Chemical and biological gradients along the Damma glacier soil chronosequence

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Studies of glacier chronosequences that integrate multiple disciplines, such as hydrological, biological and geological sciences, are a challenging but also a promising avenue to improve our knowledge of ecosystem functioning, regulation and evolution. The combination of biological tools such as plant and microbial ecology and genomics, geochemical techniques such as organic and inorganic isotope tracers, with hydrological and geomorphological tools, can provide new insights in the cycling of elements at the earth surface and their influence on ecosystem development. Most available glacier chronosquences have only a limited temporal extent, of approximately 200 years, but provide very valuable information on early ecosystem succession and initial weathering.

In this contribution, we present a first synthesis of the main results of the interdisciplinary project BigLink (http://www. cces. ethz. ch/projects/clench/BigLink) focusing on the initial phases of soil formation. As expected, mineralogy and chemistry of the soils show only minor variations at these time scales. However, some isotopic analyses showed a clear indication of weathering, especially of feldspar and mica's. In contrast, biological parameters show significant gradients, in particular with a clear build-up of soil organic carbon (SOC). Besides a very clear succession in the plant community over the chronosequence, genetic profiling also revealed clear gradients. Detailed analyses indicate that the majority of SOC is relatively labile with its pool size mainly dependent on annual primary productivity. However, a smaller pool of SOC appears to be stable over timescales of decades or longer. The Damma glacier, as many other glaciers in the Alps, readvanced in early 20th century and between 1970-1990 during colder spells. The colder climate, likely combined with some secondary sediment redeposition caused by the readvance, clearly influenced the chronosequence gradient, for instance altering the soil organic carbon concentrations. Thus, detailed reconstructions of climate variations and glacier movements are also of paramount importance to correctly interpret evolutionary gradients in soil chronosequences.

Land plant evolution, weathering, CO_2 and climate

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The rise and spread of vascular land plants during the Devonian, with continued evolution since that time, has led to major changes in the composition of the atmosphere and climate. Plants accelerate the uptake of atmospheric CO_2 via the weathering of Ca and Mg silicate minerals. This is accomplished by photosynthesis, the secretion of organic acids by roots and associated micro-organisms, the holding of moisture in soils by roots, and the re-circulating of fresh water suitable for weathering via transpiration/rainfall. The development of forests and increased weathering in the late Paleozoic, based on carbon cycle modeling, led to a global drop in atmospheric CO_2, leading to a reduced greenhouse effect, cooling and the development of continental glaciers. The burial in sediments of the un-decomposed remains of terrestrial vascular plants, in fresh water and in seawater (after transport there by rivers) contributed to the late Paleozoic drop in CO_2.

The quantification of the effects of different plants on rates of CO_2 uptake by weathering is not well established, especially for the comparison of bryophytes with primitive trees. Available data suggest an increase in weathering by a factor of about four for primitive trees vs bryophytes, but this value is based on a single field study of modern conifers vs bryophytes. Based on another combined field and laboratory study, rates of weathering by angiosperms and gymnosperms were found to be approximately equal. Better knowledge of the quantitative effects of plants on weathering allows for better elucidation of atmospheric CO_2 over time via carbon cycle modeling. What is sorely needed are more data on the weathering release of Ca and Mg by primitive trees and further work on gymnosperms, angiosperms and bryophytes.