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Microclimate affects soil chemical and mineralogical properties of cold-alpine soils of the Altai Mountains (Russia)

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Precipitation and temperature particularly influence soil properties by affecting the type and rates of chemical, biological, and physical processes. To a great extent, element leaching and weathering rates are governed by these processes. Vegetation growth and decomposition, that depend on temperature and the other environmental factors, influence weathering reactions through the production of acidity and organic ligands that may promote chemical weathering and subsequent elemental leaching.

The present work focuses on cold-alpine soils of the Altai Mountains (Siberia, Russia). The investigated field site (2380 m asl) is characterised by cold winters (with absolute minimum temperatures of -50°C; a mean temperature in January is -21°C) and cool summers (+8°C mean temperature in July). The mean annual temperature is -5.4°C. Annual precipitations are relatively low (500 mm with 20% of precipitation in July). Permafrost is widespread and occurs sometimes at a depth of 30 to 50 cm. Several studies have shown the influence of slope aspect and the resulting microclimate on soil weathering and development. There is however no unanimous agreement whether weathering is more intense on north- or south-facing slopes and whether small differences in thermal conditions may lead to detectable differences. Higher temperatures do not necessarily lead to higher weathering rates in cold alpine regions as shown by previous investigations in the European Alps. Water fluxes through the soils seemed to be more important.

We consequently investigated soils in the cold-alpine environment of the Central Altai Mountains on a very small area close to a local glacier tongue. Half of the investigated soil profiles were south-facing (5) and the other half north-facing (5). The soils have the same parent material (mica-rich till), altitude, topography, and soil age. The vegetation is alpine grassland that is partially intersected with some juniper and mosses, which portion in the soil surface increases towards the hill footslope. Soil chemical properties such as organic C, N, soil organic matter quality (using DRIFT), pH value, (oxy)hydroxides, total elemental contents (XRF), and soil mineralogy (using diagnostic treatments and XRD) were determined. The age constraint of the site was given by geomorphic studies, 14C dating of a nearby peat-bog and of the stable organic matter fraction of the soils. The soils have a Holocene age. The results showed astonishingly clearly – similarly to the European Alps – that the south-facing soils have a lower weathering state. This is expressed by statistically significant lower pH-values, more oxalate and dithionite extractable Fe, Al, Mn, and Si contents, higher C concentrations and stocks and even lower total Si- and Ca-contents at north facing sites. A similar weathering trend was also obtained from the weathering index (Ca+K)/Ti. The geochemical evolution of the soils seems also here to be enhanced at north facing sites, although very severe climatic conditions prevail. We must assume that weathering is not limited by temperature in the active layer but rather by soil moisture that seems to be higher during the warmer period in the north-facing soils. This is furthermore confirmed by the appearance of slightly evident features of an umbric soil horizon at the north-facing sites at the hill footslope. Furthermore, biodegradation seem to be less pronounced on north-facing sites compared to south-facing sites. Poorly degraded organic matter is consequently accumulated on north-facing sites. This finally gives rise to more organic and mobile organic ligands that promote weathering processes.