Weathering in the Critical Zone of the western Southern Alps

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The high solute cation and sediment fluxes of rivers draining the western Southern Alps, New Zealand, are in agreement with the generally higher chemical and physical erosion rates of mountains compared to lowlands. As such, mountains are assumed to play an important role in the global carbon cycle via supply of organic carbon to burial in the ocean and inorganic carbon sequestration through silicate weathering. To quantify silicate weathering rates, knowing the mineral sources of Ca2+ in particular is necessary. If Ca2+ is released via silicate mineral weathering by carbonic acid then atmospheric CO2 is sequestered, whereas if these ions originate from trace carbonate minerals then the process does not sequester CO2 over geological timescales. We used the chemistry of various waters (river, ground, soil) and solids (rock, saprolite, soil) to constrain the locations of weathering reactions relevant for Ca2+ release in the Critical Zone of the Hokitika River watershed. Using element ratios and sequential extractions, we identified three zones of differential weathering. Whereas ground water is dominated by calcite dissolution as indicated by high Ca/Na and Ca/Sr molar ratios, soil water exhibits low Ca/Na and Ca/Sr ratios typical for the dominance of silicate weathering, and river water is a mixture of both. Apatite dissolution occurs rapidly at the saprolite-soil boundary to almost complete depletion in the Recent and Brown Soils. The weathering front into the schist bedrock is shallow (≤ 1 m from surface) with deep bedrock weathering limited to calcite dissolution in quartz-rich veins and currently unspecified weathering reactions associated with tectonic shear zones. Our study is a first attempt to differentiate the weathering within the Critical Zone of the rapidly uplifting Southern Alps to better understand the significance of tectonics for the global long-term carbon cycle.