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Silicate Mineral Weathering Reponses to Increasing Atmospheric CO_2, Plants and Climate Evolution

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Mathematical modelling results of weathering processes in modern soils shed light on the role of land plants in weathering processes. Application to catchments in the boreal coniferous region of northern Europe demonstrates a stabilising biological feedback mechanism between hypothesised increasing atmospheric CO_2 levels and silicate mineral weathering rates. The modelled feedback response agrees within a factor of 2 to that calculated by a weathering feedback function of the type generally used in global geochemical carbon cycle models of the Earth's Phanerozoic atmospheric CO_2 history. Sensitivity analysis to model parameters indicate that the weathering feedback response is particularly sensitive to soil structure; its porosity, depth and water content. This suggests that the role of land plants to influence these soil characteristics are an important factor in the feedback to atmospheric CO_2 levels. The model yields a relatively low sensitivity of soil pH to plant productivity. This is due to more rapid decomposition of dissolved organic carbon (DOC) under warmer conditions. Because DOC fluxes strongly influence the soil water proton balance and pH, this increased decomposition rate dampens the feedback between productivity and weathering. The conceptual model of linkages between biological, geochemical and hydrological processes is based on the influence of land plants and their associated soil microbial populations to influence the dynamics of nutrient elements in soil pore waters and the resulting impact of soil pore water composition on silicate mineral weathering rates. The translation to the mathematical description of these processes is through application of mass and flux balance from first principles. Sources and sinks for elements are based on stoichiometric mass balance equations that described coupled element transformations during biomass production and decomposition, microbial decomposition of dissolved organic carbon and element mass transfer from primary silicate minerals and formation of secondary oxide and clay mineral phases. Rapid, reversible transformations are described by thermodynamic mass action and slow, irreversible processes by kinetic mass action. This process-modelling approach to quantify the biological weathering feedback to atmospheric CO_2 demonstrates the potential for a far-more mechanistic description of weathering feedback in simulations of the global geochemical carbon cycle.