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Iron Dynamics in Basalt-rich Andosols – Implications for Enhanced Rock Weathering

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Various carbon dioxide removal (CDR) techniques are currently under consideration to mitigate global warming and achieve proposed climate targets. Among these, enhanced rock weathering (ERW) aims to drawdown CO_2 by accelerating natural weathering processes utilizing abundant, low-cost materials, such as basalt. The chemical composition of basalt, particularly the role of iron (Fe), is critical for the success of this approach, as the Fe^{2+} content in basalt can vary depending on its source.

This study presents findings from a field investigation of an Icelandic Andosol. The site has received a high dust flux of basaltic material for the past 3,000 years, making this an ideal analogue to study long-term ERW applications. Our results reveal that the rapid oxidation of Fe^{2+} in the oxic zones of the system leads to the rapid precipitation of iron-(oxy)-hydroxides. In contrast, reduced conditions in deeper soil horizons favor the preservation of Fe^{2+} in both the soil waters and in Fe^{2+}-carbonate and -sulfide minerals. Notably, the formation of siderite provides an additional carbon sink, but its potential re-dissolution and oxidation of Fe^{2+}under fluctuating soil conditions can lead to the loss of this stored carbon.

The weathering of soil minerals and basaltic material increases substantially the alkalinity of soil waters. In iron-rich systems, a significant portion of this alkalinity is attributed to Fe^{2+}. However, transitioning to an oxic environment causes the re-dissolution of iron minerals, oxidation of Fe^{2+}, and the precipitation of Fe^{3+}-minerals, resulting in a loss of the alkalinity previously associated with Fe^{2+}. Field evidence demonstrates the large impact of this process on the CO_2 drawdown potential of ERW efforts. Simultaneously, the formation of new Fe^{3+}-minerals, such as ferrihydrite, provides ample surfaces to immobilize heavy metals. The formation of these Fe^{3+}-minerals may also affect nutrient cycling, including phosphate availability.