The impact of subsurface silicate weathering on the long-term C cycle

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Traditional models of the long-term C cycle assume that all volcanic C is outgassed into the atmosphere as CO2, which regulates climate and weathers silicate rocks at the Earth’s surface. However, in many volcanic settings, ascending CO2 weathers silicate rocks in the subsurface such that a substantial fraction of the volcanic C flux enters the atmosphere-ocean system as HCO3- [1, 2]. To understand the implications for climate regulation, we included a term for subsurface silicate weathering in the long-term C model developed by Kump and Arthur (1999) [3]. We also examined the role of hydrothermal calcite, which temporarily sequesters volcanic HCO3 until it dissolves at the surface later in time.

Subsurface silicate weathering indirectly affects climate by reducing the flux of volcanic C input to the atmosphere as CO2, which in turn reduces the flux of CO2 removed by surficial silicate weathering. The net result is that the atmosphere stabilizes at lower $p$CO2 values, and hence a cooler climate, compared to the case where no subsurface silicate weathering occurs. Hydrothermal calcite is only a factor when the timescale of formation and weathering exceeds 1 Myr. In this case, the atmosphere stabilizes at relatively higher $p$CO2 values but still lower levels compared to case when no subsurface silicate weathering occurs.

Nevertheless, the proportion of volcanic C introduced as HCO3 does not affect $p$CO2 and climate. Volcanic HCO3 contributions, whether from direct hydrothermal inputs or calcite dissolution, should be subtracted from measured riverine HCO3 fluxes before using the fluxes to parameterize silicate weathering feedback functions. The same logic applies to riverine fluxes of Ca and Sr, which can be used to trace HCO3 sources. The only scenario where calcite weathering may be neglected is when calcite sequesters CO2 after atmospheric injection and dissolves quickly (<1 Myr). However, this scenario does not apply to volcanic settings, such as Iceland, where the hydrothermal calcite that adds riverine HCO3 upon weathering [4] sequesters volcanic CO2 prior to atmospheric injection and is older than 1 Myr.