Weathering depletion of continental crust constrained by the carbon cycle

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The chemical makeup of Earth's continental crust is unexpected based on melting of the mantle because the magma separated from the mantle is mostly basaltic. A basalt origin of continental crust, which likely results from accumulation of the plume derived oceanic plateaus, requires massive recycling of the mafic component back to mantle through processes such as delamination. Alternatively, loss of Ca and Mg via weathering may help explain the overall andesitic composition of continental crust. However, quantifying the weathering depletion of continental crust is difficult due to the lack of knowledge on past weathering fluxes. Here we propose a new approach for estimating weathering depletion of the crust based on constraints from the carbon cycle, specifically the requiremnet of long-term balance between weathering and solid Earth degassing. Using simple models of plate tectonics coupled to progressive depletion of carbon in the mantle, we reconstruct a plausible first-order degassing history over geologic time. The oxygen isotope composition of zircons, which we interpret as recording the weathering history of continental crust, is tightly coupled with the reconstructed rate of mantle CO_2 degassing. Rapid maturation of continental crust toward felsic composition 3-1.5 Ga (billion years ago) is consistent with intense mantle degassing (and thus weathering) following the onset of plate tectonics, while the slow return back to mafic composition since 1.5 Ga may be caused by reduced CO_2 flux from the already degassed mantle. Our results suggest that at least 40%, but perhaps even all of the depletions of Ca and Mg in the continental crust can be explained by weathering recycling.