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Constraining Earth's geologic influence on the global carbon cycle during the last ice age from the planetary radiocarbon budget

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While a reinvigoration of ocean circulation and CO_2 outgassing is the leading explanation for atmospheric CO_2 rise since the Last Glacial Maximum, there is also evidence of earth's surface processes modulating the global carbon cycle during this time period. These processes are related to volcanism, as research has proposed potential carbon released near spreading centers within the Pacific Ocean. However, the magnitude and carbon cycle impact of these sources remain poorly constrained due to systematic uncertainties in establishing the stable carbon isotope mass balance [1]. Here, we invert a carbon cycle model based on observational atmospheric CO_2 and radiocarbon (^{14}C) mass balance constraints. We find only a relatively small amount of CO_2 release to be consistent with the constraints whereas up to ~1700 PgC is permissible if released to the ocean in the form of bicarbonate ion. Seawater carbonate chemistry—including pH, carbonate saturation and CO_2 partial pressure—is least impacted by carbon release with an alkalinity-to-carbon ratio (ALK:DIC) equaling that of seawater (~1.1), such that 1700 PgC release in the form of bicarbonate ion (ALK:DIC =1) results in as little as <5 ppm simulated CO_2 change.

These results allow for the possibility that volcanic systems released large amounts of carbon during the last deglaciation, as previously suggested from severe deglacial radiocarbon anomalies in the Pacific [2,3]. A large release of ^{14}C-free geologic carbon can provide local and regional radiocarbon anomalies, and our radiocarbon budget places an upper limit on the amount of carbon released. These results imply that radiocarbon evidence for significant geologic carbon release since the last ice age may not be taken as contributing to deglacial CO_2 rise, unless there is evidence for significant local acidification and corrosion of seafloor sediments. If the geologic carbon cycle is indeed more dynamic than previously thought, we may also need to rethink the approach to estimate the land/ocean carbon repartitioning from the deglacial stable carbon isotope budget.

[1] Gebbie et al. (2015), Quaternary Science Reviews 125, 144–159.[2] Rafter et al. (2019), GRL 46(23), 13950–13960. [3] Ronge et al. (2016), Nature Communications 7(1), 11487. [4] Hain et al. (2014), EPSL 394, 198–208.