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Silicon redistribution and promoted low-latitude diatom growth after Atlantic circulation recovered from deglacial meltwater discharge

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Changes in the marine silicon cycle across glacial–interglacial transitions and their impact on the biological carbon pump and atmospheric CO_2 remain debated. Proposed mechanisms include Southern Ocean silicic acid leakage, enhancing low-latitude diatom productivity either during the Last Glacial Maximum or at the onset of deglaciation, as well as deglacial redistribution of silicic acid from the abyss to the upper ocean. Using an Earth system model that explicitly represents diatom Si stoichiometry, we show that while glacial conditions enrich Southern Ocean surface waters and southern-sourced mode waters in silicic acid, strengthened stratification traps this silicon reservoir, preventing its transfer to low-latitude surface waters and limiting its impact on diatom productivity. We identify two mechanisms that release silicic acid to low-latitude surface waters. First, recovery of Atlantic overturning circulation following deglacial meltwater discharge upwells previously accumulated silicic acid, generating short-lived but pronounced peaks in tropical opal export. Second, continued warming and sea-ice retreat later during deglaciation mobilize the deep glacial silicon pool, sustaining a more persistent global enhancement of diatom productivity. Although some discrepancies in timing remain, our results reconcile previously proposed hypotheses within a unified framework and demonstrate that circulation recovery is the critical trigger linking freshwater forcing to sedimentary opal records.