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Re-Interpreting Sedimentary Carbon Isotope Mass Balances

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Abstract Text:
Carbon isotope mass balances between carbonate and organic carbon have been used to estimate the relative size of crustal carbon reservoirs and fluxes since F. E. Wickman (1941). Obtaining a steady state solution for carbonate (C_{carb}) and organic carbon (C_{org}) fluxes to marine sediments (appropriate for time scales > 10^5 yrs) requires knowledge of the isotopic compositions of coeval C_{carb} and C_{org} and an estimate of the mean $\delta^{13}C$ of carbon input to the ocean-atmosphere system (δ_n). Wickman and most subsequent workers have assumed δ_{in} was close to the mantle value (≈ -5 to -6‰) or attempted to constrain the value for volcanic degassing (≈ -4.2±0.4‰, Mason et al. 2017) as the best estimate of δ_{in}. Consideration of long-term C fluxes shows that < 25% of input to the oceans is from degassing with the majority from carbonate and silicate weathering and oxidation of kerogen (OC_{petro}) and geogenic CH_4 ($CH_{4\text{-}geo}$). $\delta^{13}C$ and $\Delta^{14}C$ data from river sediments (MOREPOC), $CH_{4\text{-}geo}$ and revised volcanic and weathering fluxes yields δ_{in} =-8.0±1.9‰, lower than previous estimates. The new mass balance with carbonate burial fluxes yields a burial fraction $f_{org} \approx 0.35$ and a C_{org}burial flux $J_{org} \approx 15$ Tmol yr^{-1}, in much better agreement with sediment inventory estimates, mostly resolving a substantial discrepancy between methods for estimating C_{org} burial. The new mass balances integrated over the late Cenozoic imply net growth of the C_{carb} and C_{org} reservoirs even after accounting for subduction, yet uncertainties remain significant.

The current mix of C sources to the oceans (degassing, weathering, oxidation) need not be fixed over time with substantial implications for interpreting $\delta^{13}C$ balances. Both the $\delta^{13}C$ of weathered sediments and the efficiency φ of oxidative weathering can vary, as can the flux of $CH_{4\text{-}geo}$. Under low O_2 conditions φ should be low and recycling of old kerogen to young sediments

more important. Apparent similarity between C_{org} content or δ_{carb} of Precambrian and Phanerozoic sediments need not imply similar rates of carbon cycling. If variations in δ_{in} are largely modulated by sediment recycling it's straightforward to derive scenarios where variations in δ_{carb} imply little corresponding variation in f_{org}.

Mason et al. 2017, *Science* 357, 290–294; Wickman 1941, *Geol. Fören. Stockholm För.* 63:4, 419-421.

Plain-Language Summary:

The use of carbon isotopes to constrain the relative rates of carbonate and organic carbon cycling has a long history. Most workers have assumed that the inputs of C to the ocean atmosphere system have isotopic compositions close to that of mantle, but that leads to substantial lower estimate of organic carbon burial and potential oxygen generation than sediment inventory approaches have found. A re-evaluation of carbon input shows that oxidation of old organic carbon and methane result in a significantly lower value for the isotopic composition of inputs, implying larger rates of carbon burial that agree much more closely with the inventory approaches.

The new results also show that the sedimentary reservoirs of carbonate and organic carbon are experiencing net growth over the last 35 million years and that should increase the oxidation state of the Earth surface environment. Consideration of carbon isotope cycling under low oxygen conditions that were characteristic of the Precambrian shows that the standard assumptions may be lead to substantial mass balance errors under such conditions,

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