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Closing the geological carbon cycle

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Geologic and geochemical processes cycle carbonate and organic carbon between sedimentary reservoirs, the ocean-atmosphere system, and the mantle. Mass, isotopic and redox balance are constraints but uncertainties remain large and the existence of closed cycles is more often assumed than demonstrated. Carbonate sedimentation exceeds carbonate weathering by ≈ 2, approximately the silicate weathering flux, even as the CO_2 budget is ≈ balanced. A growing number of studies find that carbonate sedimentation rates have increased substantially in the late Cenozoic. The organic carbon subcycle has been less easy to constrain. C_{org} oxidation includes weathering, diagenetic consumption of old kerogen in new sediments, and geogenic CH_4 oxidation. Newly compiled data on POC indicates that $\partial^{13}C$ of eroded OCpetro ≈ -22‰. Production of mature (low H/, low O/C) kerogen is associated with generation of CH_4 = -44‰. The isotopic inputs to the ocean include OCpetro and CH_4 oxidation, carbonate weathering, volcanic and metamorphic degassing, and reverse weathering. The net $\partial^{13}C$ of this input is currently ca. -7.5±1.6‰, substantially lighter than commonly assumed mantle values. Mass and isotopic mass balances yield carbonate burial = 25.2±4.0 Tmol yr^{-1} and C_{org} burial = 13.8±5.1 Tmol yr^{-1}. These new results resolve the long-standing discrepancy between isotope mass balance and inventory estimates but also imply a strong positive balance for the sedimentary C_{org} mass.

Within improved uncertainty it is possible to construct budgets that satisfy mass, isotopic and redox constraints. The flux of geogenic CH_4 is important because of its leverage on $\partial^{13}C$ and redox. The net growth of the sedimentary carbonate and C_{org} reservoirs is presently incompletely offset by subduction. The time scale of sediment destruction via subduction is long and not necessarily aligned with shorter term (but still long) carbon cycle processes. Where, what kind and how much sediment is subducted is a major control on the long term sedimentary carbon mass balance. Evolution of subduction of the carbonate-rich Tethys margin to the mostly deep water subduction around the Pacific is an important transition for the Cenozoic C cycle. The late Cenozoic shows little change in net CO_2, implying effective feedbacks on the C cycle.