Fluvial sediment transit time regulates the fate of organic carbon between source and sink

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Lowland alluvial rivers regulate the flux of particulate organic carbon (POC) between uplifted mountain ranges, productive lowland forests, and ocean basins worldwide. The timescale of sediment transfer through these rivers ultimately controls whether POC is released to, or remains isolated from the atmosphere, but the relationship between POC fate and sediment transit time is underconstrained. To study POC transformation during long distance fluvial transit, we studied the radiocarbon content of suspended POC along the Rio Bermejo (Argentina), which flows ~1300 km without tributaries. We also compare POC transformation between two reaches with opposing morphodynamics: 1) braided and aggradational and 2) incised and meandering.

Meteoric ^{10}Be data indicate that the mean sediment transit time through the Rio Bermejo fan is ~8.5 kyr. Sediment is deposited and re-mobilized ~4-5 times on average during transit, suggesting ~1.9 kyr of storage per deposition-erosion event. Through the braided reach, POC concentration and fraction modern ($F^{14}C$) increase, but POC loading remains constant, suggesting that coarse, ^{14}C-depleted headwater POC is lost to aggradation. At the transition from braided to meandering, POC concentrations and $F^{14}C$ abruptly increase, due to deep lateral erosion into stored floodplain sediment where originally POC has been turned over and replaced by modern OC. $F^{14}C$ values progressively decrease further downstream, indicating net POC preservation through multiple deposition-erosion cycles. The ^{14}C age of refractory POC increases by ~1.8 kyr through transit, suggesting ~4-5 cycles of POC turnover during total transit, coincident with the timescale of sediment deposition-erosion events.

Results of end-member isotope mixing models suggest that the downstream changes in POC and $F^{14}C$ are not caused by changing POC sources, but by the degree of POC turnover during transient storage. Our results indicate that the timescale of fluvial POC turnover is directly linked to the sediment transit time, signifying that the fate of POC in rivers globally is controlled by sediment transport and channel morphodynamics.