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Towards sustainable landscapes - Fluvial organic carbon fluxes modulated by river morphology

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Lowland alluvial rivers transfer particulate organic carbon (POC) from vegetation and soils in carbon-rich uplands to downstream ocean basins. POC can be temporarily stored in lowland floodplains, where it is subject to microbially-mediated oxidation to CO_2, but can also be stabilized through mineral protection. The balance between oxidation and stabilization therefore determines the net POC export into long-term geological sinks. Here we estimate such a balance for a natural lowland river system, the Rio Bermejo in NW Argentina, which flows across the Andean foreland basin for nearly 1300 km without tributaries.

Using meteoric ^{10}Be we estimate the mean transit time of sediment through the Rio Bermejo fluvial fan to average 8.5 kyr. However, sediment transit is faster upstream where the river is braided (~0.4 km/yr) and slower downstream where the river is meandering and laterally migrating (~0.1 km/yr). As such, POC traveling with river sediment is deposited and remobilized more frequently in the meandering section of the river. The high radiocarbon activity (fraction modern, $F^{14}C$) of POC in the braided reach suggests insufficient time for decomposition and aging. Conversely, $F^{14}C$ decreases through the meandering reach, implying that lateral migration deposits POC in point bars, where organo-mineral associations develop and inhibit POC decomposition during storage in the floodplain. Continuous lateral migration over time remobilizes this mineral-stabilized POC, as well as fresh POC from floodplain vegetation that is uprooted by collapsing river banks. We calculate the balance between POC oxidation during floodplain storage and recruitment of POC from the floodplain, and find that while sediment can spend ~8.5 kyr in fluvial transit, the river exports more POC than is oxidized during floodplain storage. These results show that mineral protection and lateral channel migration facilitate efficient POC export into long-term geological sinks.

As such, anthropogenic river engineering, such as damming and bank stabilization, may reduce fluvial POC export by preventing new development of organo-mineral associations in floodplain soils and by inhibiting erosion and transport of POC from carbon-rich floodplain forests. Our findings pave the way to develop carbon sustainable landscapes, that enhance POC preservation and act as natural CO_2 sinks.