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Dynamics of particulate organic carbon mobilization, storage, and export across river sedimentary systems

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Rivers play a key role in the global carbon cycle by actively transporting particulate organic carbon (POC) from terrestrial to marine ecosystems. Fluvially transported POC provides insights into landscape-scale terrestrial processes, including the residence times of organic matter in soils and sedimentary deposits. This review consolidates current knowledge of riverine POC, examining isotopic compositions and biomarkers to explore its sources, pathways, and fate along the fluvial continuum, influenced by tectonic, climatic, and anthropogenic drivers.

By analyzing isotopic data to assess POC sources, fluxes of biospheric and petrogenic POC have been calculated for over 130 basins, with global export rates estimated at $0.18^{+0.07}/_{-0.05}$ and $0.04^{+0.06}/_{-0.03}$ PgC year^{-1}, respectively. Biospheric POC, sourced from vegetation, soils, and aquatic productivity, presents as discrete particles or bound to minerals. This diversity in form and origin modulates its reactivity and bioavailability, spanning from annual to centennial timescales and underscoring its dynamic involvement in the carbon cycle.

The lifecycle of POC, from erosion to deposition, is governed by geomorphic and hydrodynamic mechanisms. Initial mobilization, triggered by runoff and landslides, routes POC into aquatic systems, where it undergoes physicochemical processes (e.g., sorting, exchange with colloidal and dissolved pools) and biogeochemical transformation (e.g., microbial-mediated). Transient deposition occurs in channel systems and floodplains, with eventual long-term storage in marine environments.

The dynamics of terrestrial POC are shaped by tectonic, climatic, and anthropogenic forces. Tectonic activities sculpt the landscape, influencing erosion and POC distribution, while climatic conditions, through factors like precipitation and temperature, affect POC decomposition and movement. Human activities, such as agriculture and deforestation, significantly alter POC pathways, exacerbating erosion and disturbing carbon cycles. These drivers collectively impact the mobilization and fate of POC, with profound implications for global carbon balances and climate.

POC represents a pivotal yet complex component of the global carbon cycle, acting both as a significant carbon sink through the burial of biogenic POC and as a source of CO_2 emissions via the oxidation of petrogenic POC. This delicate balance emphasizes the importance of advancing our understanding of riverine POC dynamics to accurately assess its influence on short and long-term carbon cycles and environmental effects.