Geophysical Research Abstracts
Vol. 19, EGU2017-6133, 2017
EGU General Assembly 2017
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Insights into organic carbon oxidation potential during fluvial transport from controlled laboratory and natural field experiments

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Over geologic timescales, the exchange of organic carbon (OC) between the atmosphere, biosphere and geosphere is thought to be a major control on atmospheric carbon dioxide (CO_2) concentrations, and hence global climate. The carbon fluxes from the oxidation of rock-derived OC (a CO_2 source) and erosion and transport of biospheric OC (a potential CO_2 sink) during fluvial transit are approximately the same order of magnitude or larger than those from silicate weathering (France-Lanord and Derry, 1997; Bouchez et al., 2010). Despite field data showing oxidation of OC moving downstream in lowland rivers, it is unclear if losses occur primarily during active fluvial transport within the river, where OC is in continual motion within an aerated environment, or during longer periods when OC is temporarily stored in river floodplains which may be anoxic. This represents a major knowledge gap, as the unknown location of OC oxidation (i.e. river vs. floodplain) limits our ability to develop process-based models that can be employed to predict OC losses, constrain carbon budgets, and unravel links between climate, tectonics, and erosion. To fill this gap, we investigated the potential for OC oxidation in both controlled laboratory experiments and a simplified field setting. We consider both rock-derived and biospheric OC. Our experiments simulated fluvial transport without floodplain storage, allowing mixtures of OC-rich and siliciclastic sediment to be transported for distances of $\sim$1000 km in annular flumes while making time-series measurements of OC concentration in both the solid (POC) and dissolved (DOC) loads, as well as measurements of rhenium concentration, which serves as a proxy for the oxidation of rock-derived OC. These transport experiments were compared to static, control experiments where water and sediment in the same proportion were placed in still water. Initial results for transport of OC-rich soil show similar behavior between the transport and static experiments, and no detectable OC oxidation, while separate experiments transporting crushed lignite show sediment transport enhances the oxidation of OC relative to leaching in still water; however, total OC oxidation is less than $\sim$2% of the initial OC mass. These preliminary results suggest minimal OC oxidation within our experiment, and, to the extent that such experiments represent natural transport through river systems, are consistent with the hypothesis that OC losses may occur primarily during floodplain storage rather than fluvial transport. These results are compared against new field data from a natural experiment in the Rio Bermejo, Argentina where comparing OC concentrations of modern river sediment from sediment cored in dated paleochannels of different ages allows independent estimation of the degree of OC oxidation which occurs during floodplain storage.

References:

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