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Unified prediction of organic matter preservation and degradation

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A mechanistic and predictive hierarchical model explains observed organic carbon burial efficiencies and degradation kinetics, and reveals that upper and lower limits of organic matter activation energies are key to predicting organic matter preservation and degradation rates.

Organic matter cycling forms an important part of the global carbon cycle and has been studied for many decades across multiple environments. Organic matter is consumed by microbes and animals for energy and biomass production, and through this process of mineralization, inorganic carbon and nutrients are released that sustain primary production and biogeochemical cycles. Although typically less than 1% of organic matter ultimately avoids mineralization, its accumulation in soils and sediments is an important long-term carbon sink. The reactivity and persistence of organic matter vary greatly and understanding what controls preservation and degradation rates has proven a challenge. Although degradation and preservation are two sides of the same coin, many studies focus on one or the other and rarely consider both dissolved and particulate forms. Writing in *Communications Earth & Environment*, Shang[1] presents a novel unified model that simultaneously predicts bulk organic matter preservation and degradation in aquatic systems.

Organic matter (OM) preservation and degradation is governed by multiple factors relating to OM chemistry, environmental conditions and the biological actors causing OM breakdown[2]. Natural OM is a heterogenous mixture of thousands of organic compounds that differ in composition, structure, origin, thermodynamic properties, degradation history, and how they interact with other molecules and minerals. Such factors influence degradability, with different molecules being preferentially consumed or preserved. This chemical view has its shortcomings, however, as OM preservation and degradation rates and pathways are also governed by multiple physical and chemical properties of the environment, including oxygen and nutrient availability, and temperature. In addition, organisms have specific traits and machinery to produce and consume OM and so the number, diversity and identity of consumers also play a major role. Accordingly, any generic model for OM processing should incorporate not only the heterogeneity in OM composition, but also the environmental conditions and heterotrophic community composition and functioning[3,4].

In their article, Shang[1] presents a new kinetic model of OM degradation and preservation, inspired by (quantum) statistical theory, that is mechanistic and predictive, which sets it apart from previous empirical and phenological models. Crucially, Shang's model quantitatively predicts both the observed logarithmic relation between organic carbon burial in sediments and oxygen exposure time[5] as well as empirical power-law degradation kinetics[6]. As such, Shang's hierarchical model unites OM preservation efficiencies and degradation rate patterns in a single model (Fig. 1). The model also predicts that more recalcitrant OM has a higher activation energy, which is consistent with observations[7]. Moreover, the upper and lower limits of OM activation energies are identified as key parameters to predict OM preservation and degradation rates over a wide range. This mechanistic incorporation of temperature sensitivity in the hierarchical model will be instrumental to further our knowledge on how OM preservation and degradation will respond to projected changes in temperature.

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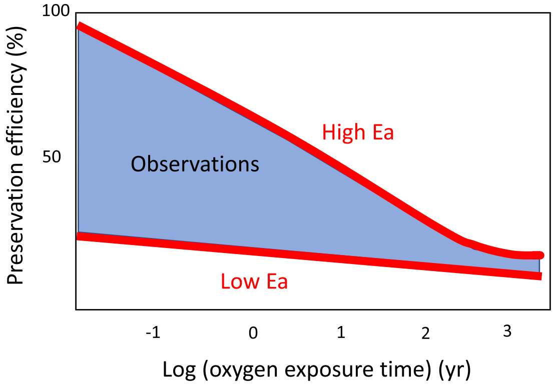

Fig. 1 Predicting organic matter preservation and degradation. Theoretical predictions (red lines) of the relationship between organic matter preservation efficiency and oxygen-exposure time encompass observations. The upper and lower limit are set by the organic matter activation energies (adapted from ref. [1]).

The hierarchical model predictions should be tested with measurable OM reactivity proxies such as the amino acid degradation index[8] and serial oxidation inferred activation energies[9]. Shang's model is predictive but rooted in traditional first-order kinetic models that do not explicitly resolve consumer communities and their metabolism. In contrast, a recently proposed quantitative model for OM accumulation that explicitly resolved the ecological dynamics of the consumers combined the stochastic release of multiple pools of OM with microbial uptake by a community of specialist and generalist consumers[4]. Although both models are generic and largely consistent with observations, they differ in basic design, that is, geochemical kinetics versus ecological dynamics as well as in their overall goals: one seeks to predict OM degradation rates and preservation whereas the other was built to explain the accumulation of dissolved OM. Integration of these two approaches would be the logical next step towards a unified theory and predictive model of OM degradation and preservation across ecosystems and covering multiple timescales.

The unified model of Shang[1] shows that organic matter in aquatic systems is broken down in a hierarchical ensemble, involving a decrease in effective kinetic barriers. Through incorporating the temperature sensitivity of organic matter degradation, we can better understand and predict future changes to this globally important carbon pool under future warming.

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Competing interests

The author declares no competing interests.

Additional information

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