The biogeochemical impact of early Paleozoic bioturbation

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Bioturbation—sediment mixing by burrowing animals—critically shapes seafloor ecology and sediment properties, as well as global marine biogeochemical cycling. Observation of strong bioturbation-biogeochemical feedbacks in modern marine environments suggests that the evolutionary development of bioturbation should have profoundly impacted contemporaneous biogeochemical (e.g., C, P, O and S) cycling. Stratigraphic archives indicate that the early Paleozoic development of bioturbation was a protracted process. Recent modeling work has suggested that even limited bioturbation may nonetheless have initiated an early Paleozoic productivity crisis and ocean-wide deoxygenation. However, the precise biogeochemical impact of early Paleozoic bioturbation has remained debated.

To further address this question, we explore a new and more fully parameterized multi-component reaction-transport diagenetic model. We observe that the relationship between bioturbation and both C-P-O and S cycling is complex and non-linear, and that not only intensity but style of bioturbation (e.g., biodiffusion vs. bioirrigation) influence the magnitude of both P recycling and S oxidation. In this light, early Paleozoic bioturbation—which was likely bioirrigation-dominated and characterized by relatively muted and shallow biodiffusional sediment mixing—may have initially only weakly influenced net S oxidation, while simultaneously mediating increased P recycling. Moreover, we find that porosity—a parameter that, although rarely explored in diagenetic models, is substantially impacted by bioturbation—strongly influences both these systems. Lastly, in contrast to previous studies, we find that bioturbation amplifies the sensitivity of the coupled C-P-O cycle to environmental perturbations.