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The substantial yet unaccounted carbon sink: Microbially-derived black carbon in cold seep sediments

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The conventional paradigm posits that marine sedimentary black carbon (BC) originates solely from terrestrial biomass and fossil-fuel combustion. However, persistent imbalances in the marine BC budget suggest substantial, yet unaccounted marine sources. This study identified and quantitatively characterized a novel microbially-derived black carbon (mBC) source generated within deep-sea cold seeps. Through high-resolution geochemical analysis of sediment cores from the Qiongdongnan Basin, we identified mBC as a significant component, evidenced by extremely depleted stable carbon isotope values in BC (–37.74‰) and total organic carbon (–55.39‰), which linked its formation to anaerobic methane oxidation. During the most recent, active seepage stage (2011–2020), mBC constituted 31–43% of total sedimentary BC, with a modern accumulation rate of 1.58–3.36 g m^{-2} yr^{-1}. Scaling this rate to global cold seep areas, we estimated that cold seeps contribute 0.52–0.79 Tg mBC yr^{-1} as a previously unrecognized sink, accounting for 4.1–5.9% of the total marine BC burial flux. Multi-proxy records further revealed a three-stage evolution of seepage activities over the past century, primarily driven by shallow fluid dynamics. The study also clarified combustion-derived BC by isolating the mBC signal, thereby validating the efficacy of regional anthropogenic emission controls after 2010. Our findings fundamentally shift the source apportionment of marine BC and reveal an important, long-overlooked carbon sequestration pathway, necessitating revisions to marine carbon cycle models to include mBC as a critical sink and proxy for past methane release.

