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A geochemical perspective on DNA preservation in sediments: implications for ecological inference and bacterial evolution

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DNA released into the environment rapidly degrades. However, DNA adsorbed to minerals is better protected against degradation than free DNA and currently there is ~0.4 Gt of extracellular DNA associated with sediments in the top 10 cm of the ocean floor. Despite limited knowledge of DNA taphonomy in sedimentary systems, including the long-term preservation of DNA on mineral surfaces, sedimentary ancient DNA (sedaDNA) is widely used to reconstruct past ecosystem dynamics. Another understudied implication of extracellular presence in sedimentary archives is the ability of bacteria to utilize this resource for gene innovations through mineral facilitated horizontal gene transfer. To address these knowledge gaps, we apply interfacial geochemical principles and a broad range of experimental approaches to investigate (1) how mineral surface interactions facilitate the preservation of DNA in sediments and (2) the ability of two common soil bacteria to acquire mineral adsorbed DNA.

We find that interfacial geochemical principles successfully resolve some inconsistencies of sedaDNA taphonomy. We provide a detailed view into the dynamics of DNA-mineral interactions and show that surface properties of minerals likely play a large role in DNA preservation. We further outline a way to increase the scope and resolution of ecosystem interpretations from eDNA by combining knowledge about mineralogic composition of substrates with their adsorption properties. Our work highlights that knowledge of sediment composition and provenance combined with mineral control of eDNA taphonomy can improve ecological inference based on complex sedimentary systems.

We also find that as DNA-mineral interactions can be a driver for evolutionary processes. Our experiments on horizontal gene transfer demonstrate that common soil bacteria can acquire DNA stored on minerals which can lead to metabolic advantages. The transformation frequencies vary significantly between mineral types and are inversely proportional to the mineral surface charge, *i.e.* their ability to immobilize DNA in solutions. We argue that the association of DNA with mineral surfaces can facilitate gene dispersal across time and space and propose mineral facilitated horizontal gene transfer as a common pathway for gene innovation in bacteria.