Microbial reworking helps preserve organic matter in sediments?

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The bulk of the organic matter (OM) in many organic rich rocks is amorphous and physically associated with clay minerals at nanometer scales. This contrasts with the OM evident in sediment traps that arrives at the sea floor consisting mainly of μm-scale organic detritus. The transformation of particulate μm-scale OM into the mineral associated fraction is a key process for long term storage in the geological record yet is poorly understood.

Heteroprophic microbial reprocessing of OM in the water column and sediment is a possible mechanism for both reducing OM size and combining it with minerals. Microbes not only break down and resynthesize OM, they utilize oxidized elements in clays as electron acceptors during respiration and actively attach to mineral surfaces [1], constructing favorable microenvironments by gluing clay particles together with extracellular polymeric substances (EPS), forming biofilms. While living microbial biomass decreases sharply with sediment depth, microbial necromass and EPS remains in close association with clays.

Past studies using geochemical tools to identify compounds specific to prokaryotes have exploited the isotopically distinct signature of certain autotrophic prokaryotes for quantification, demonstrating that the contribution of autotrophic prokaryotic carbon to sedimentary OM is minor [2]. However, this approach cannot determine the mass of OC associated with heterotrophic microbes, along with the extensive EPS networks they produce, because heterotrophic biomass is not sufficiently isotopically distinct from its feedstock.

The characteristic biofilm morphologies observed in modern settings are commonly preserved in ancient sediments. High resolution SEM and FIB-SEM images of OM-rich, immature sediments from the Miocene Monterey Formation (California) show that (A) most OM is amorphous and dispersed through the sediment in sub-micron association with clay minerals, and (B) OM is characterised by porous, honeycomb-like structure analogous to modern microbial biofilms. These findings imply that the bulk of OM in the Monterey Fmt was microbially reprocessed, resulting in the observed clay-organic association and facilitating preservation of OM through burial and diagenesis.

[1] Dong et al (2009), *American Mineralogist* **94**, 1505–1519.
[2] Hartgers et al (1994). *Nature*, **369**, 224–227.