

DARK INORGANIC CARBON FIXATION DURING HETEROTROPHIC GROWTH IN MARINE SEDIMENT

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Microbial degradation of organic matter (OM) in marine sediment is the ultimate gateway prior to long-term burial of residual OM and thus an important flux in the global carbon budget; however, quantitative estimates of microbial activity and their metabolisms in this realm are limited. Stable isotope probing (SIP) provides a valid and direct way to measure microbial community activity and metabolism. In particular, the recently-developed D₂O labelling method can trace the activity of the entire microbial community without disturbing the in situ nutrition (Wegener et al., 2012). To better quantitatively estimate the microbial activity and understand their role in the carbon cycle, we incubated marine sediments from coastal areas, including a short core (22 cm) from an intertidal flat Janssand (Wadden Sea, Germany) and surface sediment (0-6 cm) collected along a transect of the Rhône prodelta in the Gulf of Lion (North Western Mediterranean Sea), with D₂O and ¹³C-bicarbonate under anaerobic conditions.

Under natural condition with sulfate-replete artificial seawater, we found that the incorporation of D₂O and ¹³C-bicarbonate into bacterial fatty acids was faster than into archaeal intact polar di- and tetraether-derived hydrocarbons (i.e., phytane and biphytanes), which indicates that bacterial community members were growing more rapidly than archaeal members. The turnover time of the bacterial fatty acids in surface marine sediments ranged from 1.9 to 21.3 years with an avg. 7.4 years and was roughly an order of magnitude shorter than that of archaeal lipids (88–136 years with avg. 110 years). The productions rates of bacterial lipids in surface sediment ranged from 0.8 to 6.4 $\mu\text{g g}_{\text{dw}}^{-1} \text{yr}^{-1}$ (Fig. 1a) and may be related to substrate bioavailability. In contrast to archaeal lipids, significant incorporation of ¹³C-bicarbonate into bacterial fatty acids in surface sediment was observed (0.15 to 1.3 $\mu\text{g g}_{\text{dw}}^{-1} \text{yr}^{-1}$ with avg. 0.3 $\mu\text{g g}_{\text{dw}}^{-1} \text{yr}^{-1}$; Fig. 1a), indicating that the dark inorganic carbon fixation by bacteria is probably an important and widespread process in shallow coastal marine sediment. The ratio (Ra/p) of assimilation of inorganic carbon ($assim_{\text{IC}}$) into lipids to bulk lipid production ($prod_{\text{lipid}}$) based on D incorporation can reveal the metabolism of microbial community, i.e., $Ra/p < 0.3$ and ~ 1 for heterotrophs and autotrophs, respectively (Wegener et al., 2012). Our study shows that Ra/p of bacterial lipids in the surface sediment was 0.07-0.23 (Fig. 1a) under sulfate-replete conditions; therefore, the dark inorganic carbon assimilation by bacteria is probably resulted from anapleurotic (replenishing) reactions during heterotrophic growth (c.f. Sorokin 1966) rather than chemoautotrophic fixation by *Gammaproteobacteria*, as suggested recently by Dykstra et al. (2016).

To further explore the potential for inorganic C assimilation among Archaea, we incubated surface coastal marine sediments anaerobically with organic substrate (i.e., lignin) and ¹³C-bicarbonate (Fig. 1b). Interestingly, the uptake of ¹³C label from bicarbonate into archaeal lipids was stimulated by the presence of lignin. Uptake in archaeol-derived phytane was significantly higher than uptake in GDGT-derived biphytane (bp-0) and bp-2 but the relative enhancement induced by the presence of lignin was much more pronounced for the two biphytanes. The ¹³C-labeling of archaeal lipids thus suggests that both methanogens and other uncultured archaea assimilate inorganic carbon in the surface marine sediment. Dark inorganic carbon fixation may therefore be an important consequence of heterotrophic

microbial activity in marine sediments and should be considered for constraining sedimentary C fluxes. So far Ra/p values of lipid biosynthesis and ergo microbial metabolism have been calibrated for only a handful of bacteria. In the presentation, we will provide further insight in the complexity of microbial carbon flow based on compound-specific information.

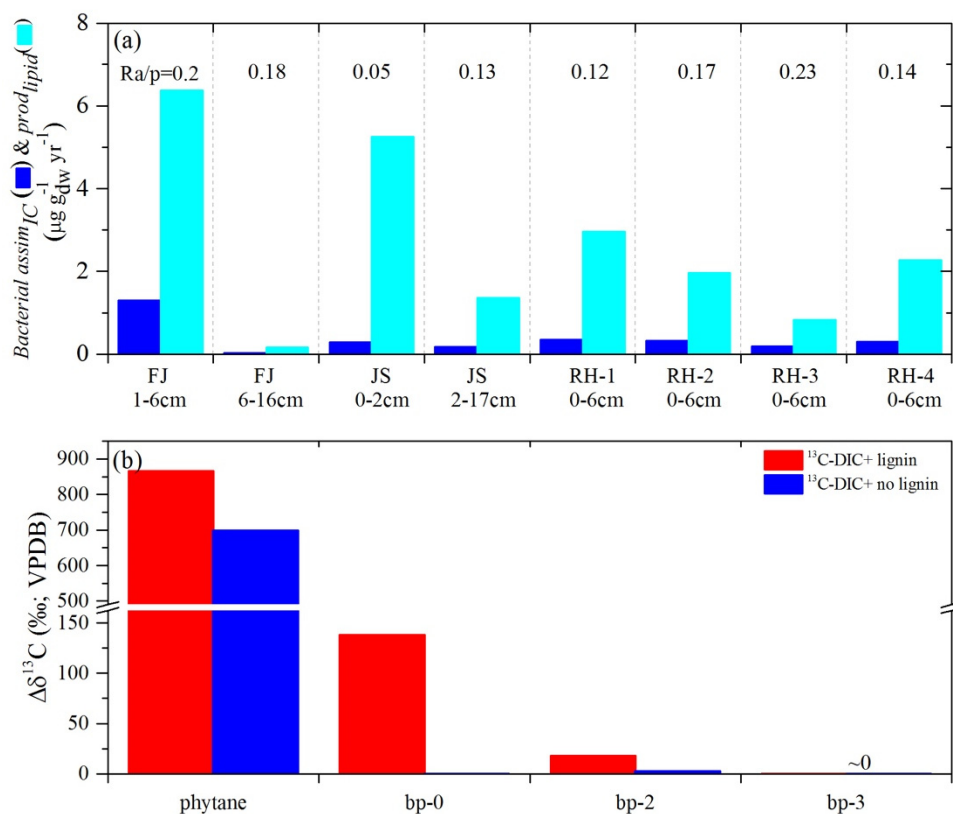


Figure 1 Summary of ^{13}C and D incorporation rate into microbial lipids in different sediments incubated in sulfate-replete artificial seawater slurry (a) or amended with lignin (b). (a): ^{13}C -bicarbonate and D_2O incorporation rate into bacterial lipids in sediments from a fjord (FJ, cited from Wegener et al., 2012), an intertidal flat Janssand (JS, Germany), and the Rhône prodelta (RH, Gulf of Lion; RH-1 to RH-4 is along a transect from prodelta to shelf) incubated with sulfate-replete medium. (b): the carbon isotope change ($\Delta\delta^{13}\text{C}$) of archaeal polar lipid-derived phytane and biphytanes with 0, 2 and 3 rings (bp-0, bp-2 and bp-3) in surface sediment (0-10 cm) from Dayang Mountain (Hangzhou Bay, China) after anaerobic incubation with ^{13}C -bicarbonate amended with/-out lignin.

References

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