Investigating the activity of methanogenic archaea in marine sediments by lipid radioisotope probing

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Methanogenesis is a terminal step in the remineralization of organic matter and one of the major microbial processes in marine sediments. However the relative importance of different carbon and energy sources involved in this process are largely unconstrained. To this aim, we applied radioisotope probing (RIP) to follow methanogen activity in marine sediments through lipid biosynthesis. The high sensitivity of RIP make it particularly suitable to follow microbial activity at short timescales. Incubation was performed in marine sediments from the Rhone delta to trace the synthesis of three specific archaeal lipids in their core and polar forms – glycerol dialkyl glycerol tetraethers (GDGTs), butanetriol dialkyl glycerol tetraethers (BDGTs) and diphytanyl diethers (archaeols) – during methanogenesis. Sediments from three depths (0-12, 80-85 and 135-140 cmbsf) were incubated up to 106 days with either ^{14}C-bicarbonate (DIC) or 2-^{14}C-acetate (ACE) as carbon source, and H_2 as major energy source. A second set of sediment samples was additionally amended with non-labeled methanol to track the use of non-competitive, methylated substrates as additional energy source for methanogenesis. ^{14}C-incorporation into the three archaeal lipid types was detected in all incubated samples. For all depths, ACE resulted in stronger ^{14}C incorporation into lipids than DIC, possibly indicating the preference of the active archaea to a heterotrophic lifestyle. Incorporation into archaeols was very high, especially at 80-85 cmbsf. Methanol seemed to favor the synthesis of GDGTs while it had no effect or inhibited the ^{14}C incorporation into archaeols and BDGTs. Using the RIP technique, we were able to determine, which lipids were actively produced during methanogenesis, and which carbon substrates and energy condition promoted ^{14}C incorporation. This work further supports the utility of specific archaeal polar lipids such as archaeols and BDGTs as biomarkers for methanogenesis.