Biotic and abiotic carbon cycling in geothermally heated sediments from the Nankai Trough

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Life strategies of members of Earth's deep biosphere are largely unknown but possibly informative for understanding early life and the deep carbon cycle. In the deep subseafloor, geothermal heating is an important environmental factor and associated with alteration of organic matter and minerals. While autotrophic organisms are thought to benefit from hydrogen releasing reactions, it is not clear whether and how heterotrophic organisms in deep sediments are stimulated by heating. This study investigated microbial carbon cycling at mesophillic, thermophilic and hyperthermophilic conditions in subseafloor sediments recovered from a high heat-flow area in the Nankai Trough (IODP Site C0012). Experiments were conducted in the temperature range of 20°C to 85°C and consisted of alive, killed and partly inhibited series for differentiation of biotic/abiotic and intermediate/terminal processes. Microbial activity, transformation of organics and metabolic intermediates were monitored via analysis of hydrogen, hydrogenase, dissolved organic matter (DOM), Fe and Mn, and volatile fatty acids. DOM was characterized by Excitation Emission Matrix Spectroscopy and Fourier Transform Ion Cyclotron Resonance Mass Spectrometry. With increasing temperature the following changes occurred compared to the control series at 20°C: (a) At mesophilic conditions, concentrations of hydrolysis and fermentation products increased and could be attributed to biotic processes. (b) At thermophilic conditions, abiotic reactions became more important and humics decomposed in both alive and killed controls. (c) At hyperthermophilic conditions, cracking of humics (mainly CHNO-N1,N2) and a significant accumulation of acetate occurred in the absence of microbial hydrolysis and fermentation. Our data suggest that the aged (7.8 Ma old) macromolecular humic substances are split into labile and refractory units during heating, and provide the basis for a new conceptual model for humics cracking. The model suggests that the combination of abiotic and biotic processes in DOM degradation is crucial for the sustenance of the deep biosphere in moderately heated sediments.