Anaerobic methanotrophy in Cretaceous methane seep deposits, Canadian High Arctic

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Over 120 ancient methane seep deposits have been found on Ellef Ringnes Island, Canadian high Arctic, within the Early Cretaceous marine shale of the Christopher Fm. The seep deposits range in size from less than 0.3 m to over 7 m height and are composed of varying proportions of background sediment and authigenic calcite. Many mounds are highly fossiliferous, including abundant bivalves, ammonites and tubeworms.

The $\delta^{13}C_{carbonate}$ values range from -55‰ to -30‰, implying an origin through oxidation of methane and subsequent carbonate deposition. The seep mounds are largely confined to one stratigraphic horizon indicating a major methane flux from the basin occurred at that time. This timing is consistent with the basin burial history and onset of thermogenic methane production, suggesting gas migration to the sea floor was synchronous with methane generation.

Mo/Al ratios of the seep deposits, in comparison to the surrounding Christopher shale host, suggests seep deposits formed in an isolated anoxic setting in an otherwise oxic environment. Biomarker analysis is consistent with this model and suggests anaerobic oxidation of methane (AOM) was most likely carried out by both ANME -1 and -2 archaea, which may represent various consortia active either temporarily or spatially. The low contents of SRB-derived biomarkers may point to a predominance of ANME-1, which are not closely tied to sulphate reducing bacteria (SRB).

Due to the local anoxic conditions during deposition, many early diagenetic carbonate phases preserve organic matter, with the exception of high magnesium botryoidal calcite, which is completely devoid of organic material. There are no hopanoids or steroids preserved in any of the methane seep deposit phases to support aerobic methanotrophy, indicating that these cements do not represent a switch to more oxic conditions as originally interpreted. Instead it is proposed that the waxing and waning of methane/ nutrient flux and its ability to move through the sediment is controlling the precipitation of the two cement phases. Alternatively, it is also possible the rate of microbial growth and methanotrophy during cementation effects the formation of the two cements.

Imposed redox frequency and amplitude flux in the study of iron biogeochemical dynamics

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The chemical stability and microbial bioavailability of iron (Fe) oxides in soils, and the coupling between carbon (C), Fe and phosphorous (P) cycles, depends on biogeochemical conditions and their temporal variability. To assess the impact of periodic redox fluctuations commonly found in variably saturated soils, a custom bioreactor system was developed in which redox fluctuations (i.e. Eh frequency and amplitude) were imposed via N_2 and O_2 gas exchange with Bisley, Puerto Rico, (CZO) soil suspensions while allowing for sub-sampling of Fe, P, CO_2 and microbial DNA. Characterization of Bisley site soils included variable temperature ^{57}Fe-Mössbauer spectroscopy (at 298, 140, 70, and 15K), X-ray diffraction (XRD) and chemical extractions of operationally defined Fe pools to evaluate Fe phase heterogeneity. Extraction data show that 20% of the total Fe oxide pool is associated with the dithionite-citrate-bicarbonate (DCB) fraction, of which half is associated with the citrate-ascorbic acid (CA) fraction. Mössbauer spectra show quadrapole distribution sites for Fe^{II}/Fe^{III} in clay and a hyperfine distribution site (sextet) that closely resembles that of nano-goethite. The difference between averaged sextet spectral areas at 70 and 15K (11.7% relative abundance) may correlate with the % abundance of CA extracted Fe. Currently, microbial fingerprinting techniques (i.e. denaturing gradient gel electrophoresis (DGGE) and ribosomal intergenic transcribed spacer analysis (RISA)) are being used to characterize changes in bacterial community composition in response to bioreactor redox oscillations. Finally, process-based kinetic model simulations have been used to describe and test mechanisms of Fe reduction, abiotic transformations, phase partitioning, and microbial population growth in the Bisley (CZO) soils. Preliminary simulations show that Fe concentrations can be reproduced closely by adjusting the time period in oxic and anoxic cycles in accord with experimental conditions.