Methane consumption ecosystem modeling around cold seepage

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Cold seepages and hydrothermal activities are characterized as rapid upward transports of methane from deeper part of geological structures to the seafloors. Prior to reach the seafloors, when methane meets downwards diffusing seawater sulfate, it is oxidized anaerobically by a consortium of microorganisms that use sulfate as an oxidant, producing sulfide. The anaerobic oxidation of methane and anaerobic sulfate reduction are clarified as a coupled biological activity. A significant portion of the bicarbonate produced after the sulfate reduction as authigenic carbonate near the seafloor. On the seafloors just above the coupled consortium of microorganisms, usually sulfur oxidizing microorganisms are visible. They are called bacterial mats. When the fluid flow rates are slow, dissolved methane can be completely oxidized by this process. However, when the fluid flow rates are fast, direct methane bubbling occurs and chemosynthesis-immobilization communities such as tubeworms and clams distribute around the bacterial mats and the bubbling locations.

A mass balance ecosystem model around the methane emission point in and on seafloor and the upper water column is studied through the analyses of natural cold seepages and hydrothermal activities in the research. The biogeochemical ecosystem model is numerically created. The outline structure of the model is introduced and some preliminary examination results from the test calculations are discussed.

After the bubbling, methane goes into the upper water column and the dissolution and dispersion start. These processes are expressed as a physical model under 3-dimentional current structure. It is necessary to add methane oxidization by bacteria in the water column. It is expected to increase the ratio of oxidization with the methane existing time in the water column.

The three passes in and on seafloor in conjunction with methane emission mentioned in the previous section, the carbonate formation, the immobilization, and the bubbling, and the additional physical and biological processes in the upper water column are schematically summarized in the figure.

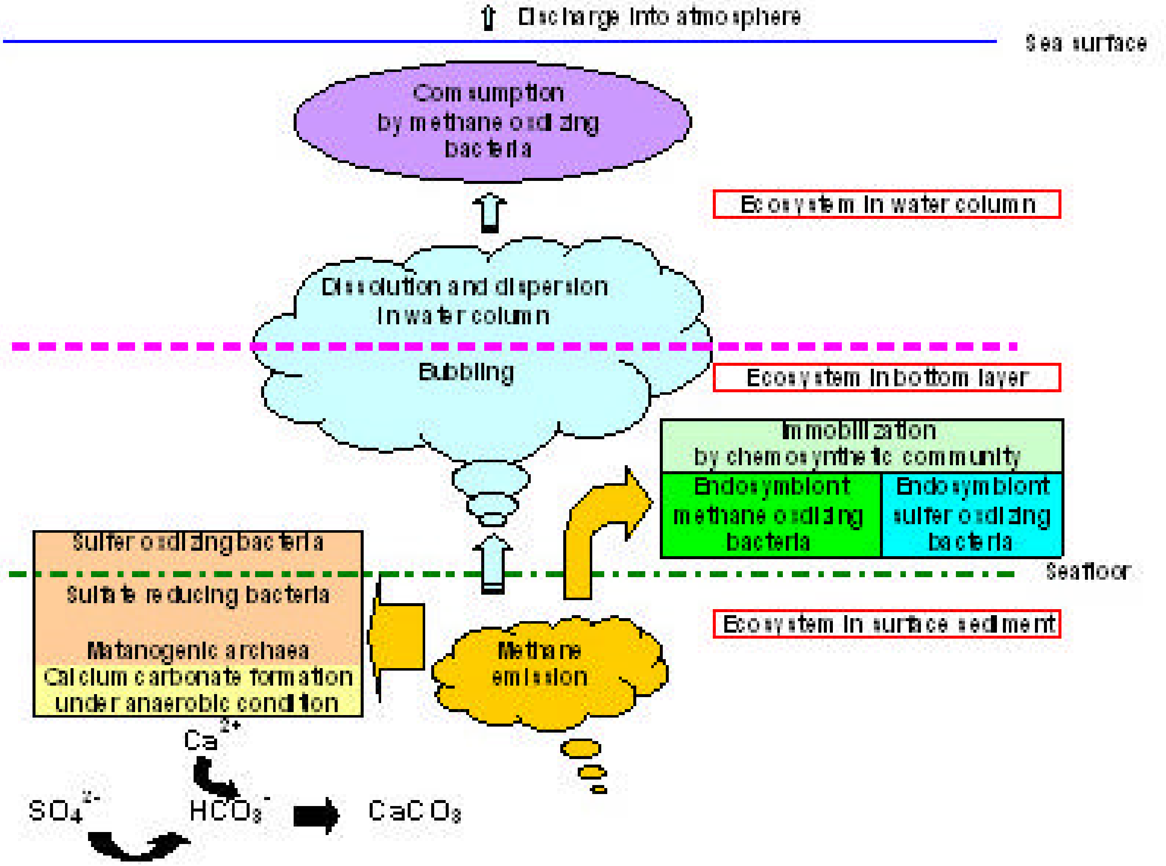
Because CANDI and C. CANDI are well coordinated biogeochemical and bicarbonate process models, the authors selected them as the main structure of the seafloor ecosystem model. In order to understand the programs themselves, the parameters and conditions in calculations, and the subroutines in CANDI and C. CANDI, some test calculations were conducted.

The calculation started with initial conditions as sulfate concentration equals sea water at the top of sediment column and methane concentration equals given value at the bottom of sediment column, normally 15cm. Depending on the biogeochemical actions, concentration profiles of sulfate and methane in the sediment column changed with time. Finally SMI was clearly created. Depending on increase of the methane concentration, SMI moved up near surface area. This type SMI movement is clearly recognized from geochemical analyses of sediment core samples.

Additional calculation started with an initial carbonate concentration of zero throughout the sediment column. Precipitation of authigenic calcite and aragonite decreases porosity, while carbonate dissolution induces a porosity increase. After each time step, the porosity in each sediment layer is recalculated, as a function of the changing $CaCO3$ concentration. By the formation of authigenic carbonate, the fluid flow velocity should decrease with decreasing porosity.

The results of test calculation showed the location of calcium carbonate formation is just above SMI. The other two profiles of density and pH showed good relationships with the other results.

Thus, effectiveness of CANDI and C. CANDI was clearly examined from these test calculations.


Discharge into atmosphere
Sea surface
Consumption by methane oxidizing bacteria
Ecosystem in water column
Dissolution and dispersion in water column
Bubbling
Ecosystem in bottom layer
Immobilization by chemosynthetic community
Endosymbiont methane oxidizing bacteria
Endosymbiont sulfer oxidizing bacteria
Seafloor
Ecosystem in surface sediment
Sulfer oxidizing bacteria
Sulfate reducing bacteria
Matanogenic archaea
Calcium carbonate formation under anaerobic condition
Methane emission
Ca^{2+}
SO_4^{2-}
HCO_3^-
$CaCO_3$