Evaluation of Methane Hydrate Accumulation Mechanism by Basin Modeling - A Case Study of Eastern Nankai Trough Area -

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We have developed 2-D numerical simulator 'SIGMA-MH' for methane hydrate (MH) accumulation in order to simulate geological/physicochemical phenomena related to MH deposits formation in deepwater sediment and to clarify controlling factors for MH accumulation. SIGMA-MH is a modified version of 'SIGMA-2D', a 2-D basin simulator for petroleum system developed by JOGMEC. SIGMA-MH has models such as microbial methane generation model, methane solubility model in water, and MH formation / dissociation model, with which MH accumulation can be simulated.

An empirical model is used for microbial methane generation model. In this model, maximum gas generation rate is estimated from organic accumulation rate, which are derived from ODP (Ocean Drilling Program) gas sample analysis [Brown, 2005]. Kinetic reaction model is applied for MH formation/dissociation. MH formation/dissociation rate is expressed as a function of the difference between the fugacity of methane at gas phase and the fugacity of methane at the three-phase equilibrium for MH-water-methane gas [Kim et al., 1987]. A model by Claypool and Kaplan(1974) is used for three-phase equilibrium curve for brine. To model the dissolution of methane in water, Davie et al.(2004) is used for the temperature under 300[K], and Schoell(2003) for the temperature above 300[K]. The decrease of gas solubility in the existence of MH is expressed by those models.

Using SIGMA-MH, case studies were conducted for two sections including boreholes at Tokai-Oki and Daini-Atsumi Knoll area where MH concentration was detected. The result of Tokai-Oki area is presented here.

Geological structure used in the simulation was estimated by seismic survey. Rock facies were determined by logging and core sample. Heat flow was calibrated by present temperature measured by geothermometer. Base case for paleo-water depth history was built based on microfossil analysis, and additional two cases which are shallow case and deep case were conducted as a sensitivity analysis.

As a result of simulation, (1)methane gas was generated as layers including organic matter were deposited. (2)Methane gas reacted with water and turned to MH. (3)As sedimentation progressed, MH was dissociated to methane gas and water by temperature increase. (4)Methane on free phase and solution phase moved up along layers. (5)MH accumulated at MH-stable zone. A series of recycling process on MH deposit formation was reproduced.

MH accumulation estimated by simulation nearly corresponds to that of actual borehole. The phenomena that methane gas migrates through permeable sand layers and MH accumulates in them suggests that permeability are a key of MH accumulation. Phenomena that pressure dropped with upheaval (or decrease of water depth) and MH resolved into gas, were reproduced. It was found that paleo-water depth plays an important role because it affects on present MH accumulation.

As mentioned above, SIGMA-MH was developed as a tool for evaluating controlling factor and mechanism of MH accumulation, and was applied to Eastern Nankai Trough area. In the process of application, a problem has arisen that much time is needed for calculation in the case that thin layer exists, that water depth changes rapidly, or that fluid flow rate is high because of high permeability of layer. In addition, simulation cannot be executed when reaction rate is high. For future work, it is necessary to clarify the limitation of parameters through many case studies in various settings.

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