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Field Scale Simulation for Consolidation and Gas Production Behavior during Depressurization Process of Methane Hydrate in Marine Sediments

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Abstract

Methane hydrate (MH) is one of the potential resources of natural gas in the near future, because large amount of MH exists in marine sediments or in permafrost regions worldwide. Depressurization process is regarded as the most effective process for gas recovery from the viewpoint of gas productivity and economical efficiency, compared with the other in-situ dissociation processes of MH. However, increase of effective stress during depressurization causes consolidation of MH sediments and permeability reduction. As a result, reduction of gas productivity is also supposed. Therefore, it is very important to understand the behavior in MH reservoir, especially in developing the extraction system for MH, and when considering the environmental impacts due to the development. In this study, we formulated absolute permeability with MH formation that was considered porosity reduction due to consolidation of MH sediment. Then, using derived equation, some simulation run was carried out to discuss the effect of permeability change due to consolidation of sediments on dissociation and gas production behavior.

Introduction

Methane hydrate (MH) is ice-like solid substance in which water molecule structure contains embedded methane molecules under low-temperature and high-pressure conditions[1]. When 1 m^3 of MH is decomposed, about 150m^3 of methane gas is produced. MH is one of the potential resources of natural gas in the near future, because the large amount of reservoir exists in marine sediments or in permafrost regions worldwide[2-5]. Some extraction methods of MH from the reservoir in marine sediments have been proposed, such as depressurization, thermal stimulation and inhibitor injection[6]. These are all based on the in-situ dissociation process of MH that is transformed into methane gas and water. Only methane gas can be produced from the reservoirs in marine sediments. Depressurization process is regarded as the most effective process for gas recovery from the viewpoint of gas productivity and economical efficiency, compared with the other in-situ dissociation processes of MH[7]. However, increase of effective stress during depressurization causes consolidation of MH sediments and permeability reduction[8]. As a result, reduction of gas productivity is also supposed. Therefore, it is very important to understand the behavior in MH reservoir, especially in developing the extraction system for MH, and when considering the environmental impacts due to the development.

In addition, the results for the preliminary drilling in Nankai trough carried out in 2003 indicated that 1) MH reservoirs existing in the adjacent sea of Japan were not always uniform, 2) the reservoirs had some heterogeneous structures and were characterized by permeability anisotropy due to alternation of strata consisting of sand and mud layers[9]. Therefore, it is necessary to consider gas and water flow in horizontal direction in sand-layer, because the existence low permeable mud-layer interferes vertical fluid migration. Especially, in the process of depressurization, the effect of vertical consolidation on horizontal permeability change must be discussed, as shown in Figure1.

In this study, for the purpose of introduction into the numerical simulator for MH dissociation process, we carried out an experimental study for estimation of permeability in a MH reservoir with involving consolidation of the sediments due to reduction of effective stress in pore space. Considering porosity change due to consolidation, consolidation-permeation tests under the horizontal radial flow condition were conducted to formulate absolute permeability as a function of porosity in addition to MH saturation. Then, we have conducted the field scale simulation to clarify consolidation and gas production