Relation Between Pore-size Distribution and Permeability of Sediment

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In order to clarify the relation between permeability and these properties, the permeability, grain-size distribution, porosity, pore-size distribution, and surface-to-volume ratio of glass beads and sandy sediments have been measured. A semi-empirical (SE) equation for the permeability of glass beads and sandy sediment has been derived based on the Kozeny-Carman equation using pore-size distribution and porosity measured by mercury porosimetry. This SE equation has been approximated by the relation of the porosity, pore-size distribution, tortuosity, and surface-to-volume ratio of the sediment. The permeabilities calculated by the SE equation correspond well to the permeability measured by water flow. Furthermore, techniques for converting NMR-T2 distribution developed in our previous work were applied in order to obtain the pore-size distribution with higher spatial resolution.

KEY WORDS: methane hydrates, NMR, permeability, porosity, pore-size distribution.

INTRODUCTION

Methane hydrates in sediment are expected to be developed as a resource for natural gas and have been studied as a possible future energy resource. In-situ dissociation of natural gas hydrate is necessary in order to commercially recover natural gas from the natural gas-hydrate-bearing sediment, i.e., mainly methane-hydrate-bearing sediment. The exploitation of methane hydrate (MH) and methods of producing methane gas from methane hydrate, such as (1) the depressurization method (Sakamoto 2007a, 2007b), (2) the thermal stimulation method (Sakamoto 2007a, 2007b), and (3) the inhibitor injection method (Kawamura 2006) have been proposed. In any method, gas permeability and water permeability in methane-hydrate-bearing sediments are important factors for estimating the efficiency of methane gas production. The sediment permeability is generally determined by measurement using gas or liquid flows. For example, the permeability of a methane-hydrate-bearing layer is measured by using gas or liquid flows for MH sediment, which is explored using a Pressure-Temperature Core Sampler (PTCS). The permeability of methane-hydrate-bearing sediment is considerably affected by several properties of sediment, e.g., pore-size distribution, porosity, cementing, MH production characteristics, and MH saturation. Furthermore, permeability measurements of methane-hydrate-bearing sediments using gas or liquid flow could cause reformation and/or heterogeneous dissociation of MH. Therefore, the calculation of permeability using mercury porosimetry for dried sandy sediment and proton nuclear magnetic resonance (NMR) has been proposed as an alternate method. In well-site measurements, the permeability of the methane-hydrate-bearing layer is generally analyzed by the NMR method, and the pressure transient data by a Modular Dynamics Tester (MDT) (Anderson, 2008).

In order to obtain data for understanding methane hydrate occurrence and estimating natural reserves, the Ministry of Economy, Trade and Industry, Japan (METI) drilled exploratory test wells “Tokaioki to Kumano-nada” from January to May, 2004 (Fujii, 2005, Tsuji, 2004). As a result of PTCS coring in the Nankai Trough METI exploratory test, methane hydrates were confirmed in the pore space of the turbidite layer. According to the grain-size analysis of natural methane hydrate sediment, hydrate-bearing sediment is composed of very-fine to fine-grain sand and medium-grain sand (Fujii, 2005, Tsuji, 2004). In laboratory experiments, it was reported that the permeability of sandy sediment with a mixture of medium-grain sand and fine sand had decreased two orders of magnitude with an increased ratio of fine sand in the sediment pores.

In order to simulate the permeability of natural hydrate-bearing sediment, it is necessary to elucidate the relationships among permeability, apparent pore-size distribution, and grain-size distribution.

Mercury porosimetry is a very powerful tool for measuring the pore-size distribution of reservoir rock and sandstone (Uchida 1987). Por-