

## **Assessment of the Absolute Permeability of Natural Methane Hydrate Sediments by Microfocus X-ray Computed Tomography**

*Yusuke Jin, Jiro Nagao, Junko Hayashi, Kiyofumi Suzuki, Hideki Minagawa, Takao Ebinuma, and Hideo Narita*  
Methane Hydrate Research Laboratory, National Institute of Advanced Industrial Science and Technology (AIST)  
Sapporo, Japan

### **ABSTRACT**

This paper examines the newly assessment of permeability of sediments via the correlation between the absolute permeability and the pore network in sediment. The continuous pore channel, which allows gas and water flow, was analyzed from the three-dimensional sediment images using a microfocus X-ray computed-tomography system. The results clarified that the proportion of the horizontal-continuous pore channel in terms of direction is a dominant factor in determining the absolute permeability. The absolute permeability of the sediment correlated well with the distribution of the continuous pore channel.

**KEY WORDS:** permeability; X-ray computed tomography; pore network; gas hydrate, sediment.

### **INTRODUCTION**

The gas hydrate is crystalline clathrate of gas and water molecules. Hydrates have been studied over a wide range from fundamentals to field applications because of their unique structure and characteristic. Natural-gas hydrates, store the natural gas molecules in a water formation framework and are widely distributed in oceanic and permafrost sediments (Sloan, 1998). Gasses in the natural-gas hydrate sediment are primarily methane molecules (Kvenvolden, 1995) and are expected to become a new energy resource. The production of natural gas from oceanic and permafrost sediments is currently being developed using such methods as depressurization, thermal stimulation, and injection of hydrate inhibitors (Moridis, Collett, Dallimore, Satoh, Hancock and Weatherill, 2004). It is important to understand the physical properties of sediment in investigations of structural properties, such as permeability, hydrate saturation, and sediment porosity, since these properties are essential to the development of natural gas production. The porosity is particularly important for material flow in sediment. Therefore many reports have been published on the relationship between porosity and permeability (Arns, Knackstedt and Martys, 2005; Bernabe, Mok and Evans, 2003; Koponen, Kataja and Timonen, 1997; Noiriell, Gouze and Bernard, 2004; Pape, Clauser and Iffland, 2000; Quispe, Rozas and Toledo, 2005; Singh and Mohanty, 2000). The gas and water appear to flow in continuous pores of sediment during the hydrate decomposition, and thus it is necessary to investigate the pore network to understand the material flow in the sediment. Studies of the pore network are essential not only to

petroleum engineering but also to chemical engineering one.

The imaging of sediment is an advanced method for understanding the structural property non-destructively. X-ray computed tomography (CT) is a useful imaging tool for non-destructively acquiring a three-dimensional (3-D) image of an object. Structural studies of sediment and material flow in sediment has been conducted using X-ray CT (Auzerais, Dunsmuir, Ferreol, Martys, Olson, Ramakrishnan, Rothman and Schwartz, 1996; Crestana, Mascarenhas, and Pozzi-Mucelli, 1985; Harold and Wellington, 1987; Hunt, Engler, and Bajsarowicz, 1988; Sato, Takeya, Nagao, Jin, Hayashi, Kamata, Minagawa, Ebinuma and Narita, 2005; Taud, Martinez-Angeles, Parrot and Hernandez-Escobedo, 2005; Warner, Nieber, Moore, and Geise, 1989). Recently, Sato, Takeya, Nagao, Jin, Hayashi, Kamata, Minagawa, Ebinuma and Narita (2005) applied a high-speed X-ray CT apparatus and determined the distribution of density and hydrate saturation of artificial methane hydrate sediments. Almost structural investigation of sediment has been performed by medical X-ray CT system. The images obtained from medical X-ray CT do not achieve sufficient spatial resolution for analyzing pore network of sediment. Recently, a microfocus X-ray CT has been applied to investigate the small-scale features of objects since it offers greater spatial resolution (Jin, Takeya, Hayashi, Nagao, Kamata, Ebinuma and Narita, 2004; Jin, Nagao, Takeya, Jin, Hayashi, Kamata, Ebinuma and Narita, 2006) in which the porosity and hydrate saturation of artificial methane-hydrate sediment were determined. Here, we reported distribution and feature of the continuous pore characterized by a microfocus X-ray CT imaging. The relationship between the continuous pore, which allows gas and water flow, and the absolute permeability of natural methane gas hydrate sediment based on 3-D image data is discussed. The investigation of the pore network in natural sediments would clarify the predominant factor of the material-flow process and examines the newly assessment of the absolute permeability in sediment.

### **EXPERIMENTS**

#### *Samples*

We measured the absolute permeability in five natural-gas hydrate sediments bored at the Nankai Trough, Japan. The samples were the part of sand layer and had a few components of silt and clay particles.