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Analysis of Pore Structure and Water Permeation Property of a Shale Rock by Means of X-Ray CT

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Abstract

In this study, pore structures and water permeation property of a shale rock are analyzed by means of X-ray CT. The target samples are produced Kushiro district in Hokkaido, Japan. Underground of this area is consisted by Cretaceous formation. Firstly, one dimensional permeation tests were performed by using core sample retrieved from Cretaceous formation, and intrinsic permeability was evaluated. Secondly, the internal structure of rock samples was observed by X-ray CT scanner, and porosity distributions were also evaluated by comparing CT image data between the dry and the water-saturated conditions. It was found that Cretaceous formation has relatively low permeability as k=10^{-19} ~ 10^{-18} m^2. It was also found that the porosity of each sample was approximately 7%~13%, however, porosity distribution was not uniform, and was strongly influenced by density distribution in samples.

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Keywords: porosity; permeability; shale; X-ray CT

1. Introduction

Natural gas/oil has been developed all over the world, and most of gas/oil has been supplied from so called conventional natural gas/oil deposits for long time. However, as technology and geological knowledge is advancing, many unconventional natural gas/oil deposits have been discovered, and total amount of supplied energy is increasing [1]. The representative of unconventional natural energy deposits is shale rock layers [1]. In Japan also,

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there are several promising shale rock layers as gas/oil reservoirs [2], and certain amount of gas/oil deposits are inspected.

In this study, pore structures and water permeation property of a shale rock are analyzed by means of X-ray CT. The target samples are produced Kushiro district in Hokkaido, Japan. Underground of this area is consisted by Cretaceous formation. This is mainly formed by sandy shale and it is spreading under Kushiro coal seam. It is estimated that huge amount of methane gas exists in the Cretaceous formation [3], however, the origin of the methane and the storage process in the formation including its total amount are still not clear. The purpose of this study is to obtain fundamental characteristics or properties of the shale rocks located at Kushiro, such as nominal porosity, permeability, porosity and density distributions. Here, nominal porosity is evaluated through water absorption tests. One dimensional permeation tests are performed, and intrinsic permeability of the shale samples are evaluated. In order to inspect the internal structure of the shale, X-ray CT method is applied. From the CT image data, the internal structure of rock samples is discussed, and porosity distributions are also evaluated by comparing CT image data between the dry and the water-saturated conditions.

2. Rock sample and its porosity

The target samples are produced at Kushiro district in Hokkaido, Japan (Fig. 1). Here, Kushiro Coal Mine Co. Ltd. is producing approximately 500 000 tons of coal every year, and the bed rock below the coal seams is consisted by Cretaceous formation. This is mainly formed by sandy shale and the shale layer spread up to 4 000 m depth. In this shale layer, it is expected a certain amount of methane gas is stored, however, precious characteristics of the shale is still unrevealed.

The rock samples used in this study are drilled from 160m to 250 depth of this site. An example photo of the sample in dry condition is shown in Fig. 2. This is dilled vertical direction. As this figure shows, the grain size is very small. Some sedimentary layers are also observed perpendicular to the core axis, that is horizontal direction, in some samples. Here seven pieces of rock samples (named Sample A to G) are used for following permeation tests and X-ray CT analysis.

In order to evaluate porosities of samples, water absorption tests are conducted, and the porosity is evaluated from the weight differences between dry condition and fully saturated condition. Here, water absorption tests are conducted under the vacuum condition, and the saturation process is also monitored. The temporary change of weight is shown in Fig.3. The vertical axis represents the normalized weight and that the temporal weight M is normalized by initial weight M_0. As this figure shows, the characteristic point of the samples is that the weight gradually and slowly increases at the beginning of absorption process, and that it takes more than 20 to 25 days until the sample is fully saturated. The evaluated porosities together with weight change during absorption tests are summarized in Table 1. The evaluated values of porosities are approximately in the range between 7% and 13%, and the values are almost same as the ones of shales which product oil and gas [4, 5, 6].

Fig. 1. Location of Kushiro.

Fig. 2. View of Kushiro shale sample.