Study of Pore Size Evaluation for Low Permeability Rock Core Sample

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ABSTRACT

Characteristics of tight rocks in hydrocarbon reservoirs is important to predict reservoir performance. Especially, it is difficult to accurately evaluate permeability which is affected by pore connectivity.

In this study, we conducted experiments to analyze pore connectivity including the pore shape and network with low permeability rock samples. Low permeability rock samples were collected from the outcrops in Japan. The samples are siltstone and silty mudstone. The permeability of the samples is less than 1nd, whereas the porosity is around 5 %. The N2 adsorption, Mercury injection and NMR tests were conducted to obtain pore size distributions. The core samples used here contains clays. Special cares were taken to dry the core samples for pre-treatment of the N2 adsorption tests. N2 adsorption tests were conducted repeatedly for hysteresis loops. Results shows that the samples have macropores by adsorption process and micropores by desorption process using t-plot analysis. This indicates that the pore of samples has the wide range pore size and the pore shape consists of the slit and cylinder. In addition, we conducted the numerical analysis by BJH and INNES, the pore size is confirmed to be from 0.6 nm to 6um.

INTRODUCTION

Characteristics of tight rocks in hydrocarbon reservoirs is important to predict reservoir performance. It is difficult to make measurements of properties in low permeability rocks such as shale gas and tight oil formations with conventional experimental methods. Evaluation methods are thus proposed and discussed for low permeability rocks. In this study, we conducted to evaluate characteristics based on the pore size distributions of low permeability rocks.

EVALUATION OF PORE SIZE DISTRIBUTION

Mercury injection, gas adsorption and NMR methods are often used for evaluating pore throat/size distribution of rocks. In a mercury injection method, pore throat distribution is derived with the Washburn equation using injection pressure and injected volume when mercury is injected into a rock sample. In a gas adsorption method, an amount of physical adsorption of gas is measured at equilibrium pressure as gas is injected into a rock sample under the liquefied point of the injected gas, and pore diameter is calculated from the amount of physical adsorption in consideration of the molecular size of gas and shape of

the pores[1][2]. In a NMR method pore size distribution is obtained from the volume of fluid that contains hydrogen atoms by measuring T2 relaxation time.
In the mercury injection and gas adsorption methods the pores should be connected and the pore size is limited by the atom size of used fluids. The very small pore size cannot be measured with these methods. On the other hand, the NMR method has no limitation of the pore connectivity. The NMR method does not convert pore size distribution from T2 relaxation time directly although it allows us to evaluate hydrocarbons and water in unconnected pores of recovered reservoir rocks. Not only the NMR method but also the mercury injection and gas adsorption methods is thus required to evaluate rocks that naturally have wide variety of pore shape and size. This study describes the results of hysteresis analysis by the gas adsorption method in order to initiate comprehensive evaluation of the pore size and connectivity.

EXPERIMENT AND RESULTS

A silty mudstone sample obtained from the formation from 200 to 1000m below subsea level was used to evaluate pore size distribution with NMR, mercury injection and nitrogen adsorption methods in this study. The rock sample used here has about 0.05 of porosity derived from a NMR method and less than 1nd of air permeability (Table 1). In the NMR, the mercury injection and the nitrogen adsorption methods, the rock samples were shaped into core plugs in 1cm length, about 5mm debris and particle size less than 250um mesh, respectively. Hysteresis analysis was conducted with decreasing the upper limit pressure in the nitrogen adsorption method.
Fig. 1 shows the pore throat distributions from mercury injection. The pore tt distributions become smaller as the depth increases. The peak of pore throat distribution is 2.9E-02um in No.2 sample, whereas it is 5.1E-03um in No.8 sample. In addition the surface area of the pore throat distribution curves decreases as the depth increases as shown in Fig.2.
Fig. 3 shows the adsorption and desorption isotherms. According to the IUPAC classification of gas physisorption isotherms, these rock samples are categorized as the type IV.
Fig. 4 shows the t-plot[3] analysis based on the isotherms. This suggests that the pore size distributions of the rock samples are relatively wider and the shape of pores is the type of slit. To further understand the shape of the pores, the BJH and INNES[4] analyses were conducted using the adsorption and the desorption isotherms, respectively (Fig.5). By comparing these analyses and NMR measurements it was suggested that the pores that were observed pore size distribution with a single peak from the NMR method comprise of two shapes of slit and cylinder.

CONCLUSION

We evaluated the shape of pores in silty mudstone rocks that have low permeability using hysteresis analysis based on the nitrogen adsorption method. As a result, the shape of pores was identified to be combinations of slit and cylindrical shapes although the pores represented a single peak pore size distribution from the NMR method. The hysteresis methods used here are useful to better understand flow characteristics of the low

permeability rocks. We will continue to evaluate various types of rocks with a series of measurements presented in this study.

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Table 1Properties of rock core samples.

Core No.	Depth m	Diameter cm	Length cm	Dry weight g	NMR porosity frac.
1	201.05	2.461	5.055	58.74	0.0578
2	201.13	2.464	4.965	57.92	0.0521
3	202.69	2.536	4.891	60.38	0.0599
4	448.79	2.466	4.953	59.60	0.0511
5	753.68	2.521	5.223	66.77	0.0306
6	753.92	2.523	5.061	64.24	0.0305
7	754.71	2.524	5.173	64.00	0.0613
8	998.24	2.522	5.21	67.62	0.0416
9	998.09	2.529	3.221	41.22	0.0533

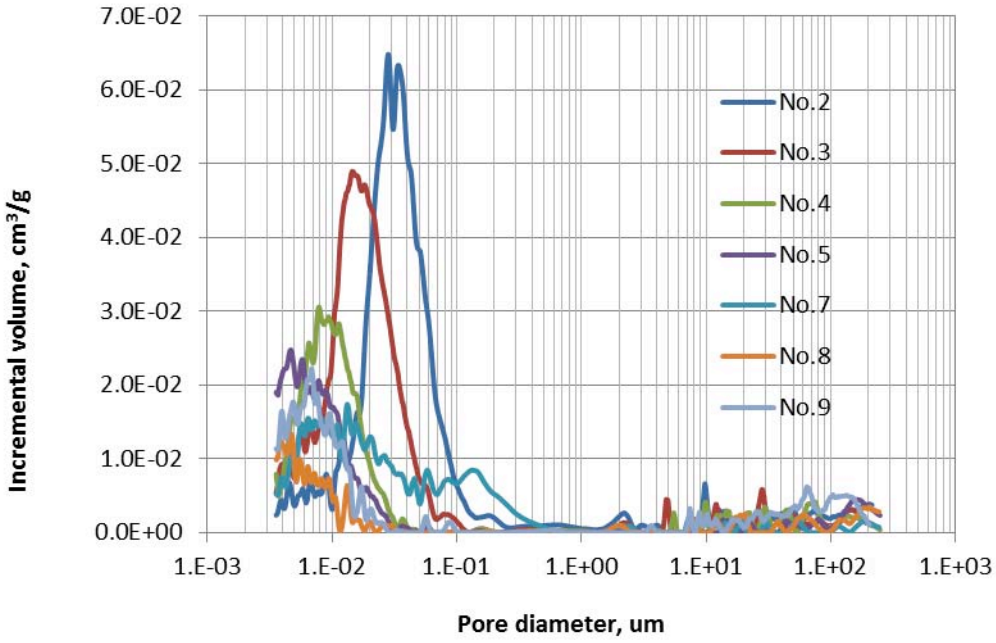

Fig.1 Pore throat distribution by MICP.

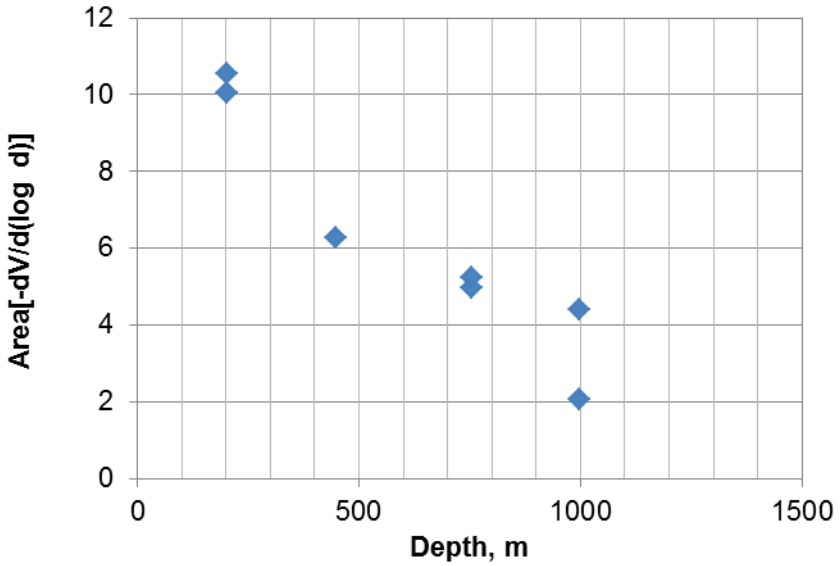

Fig.2 The correlation between depth and surface area.

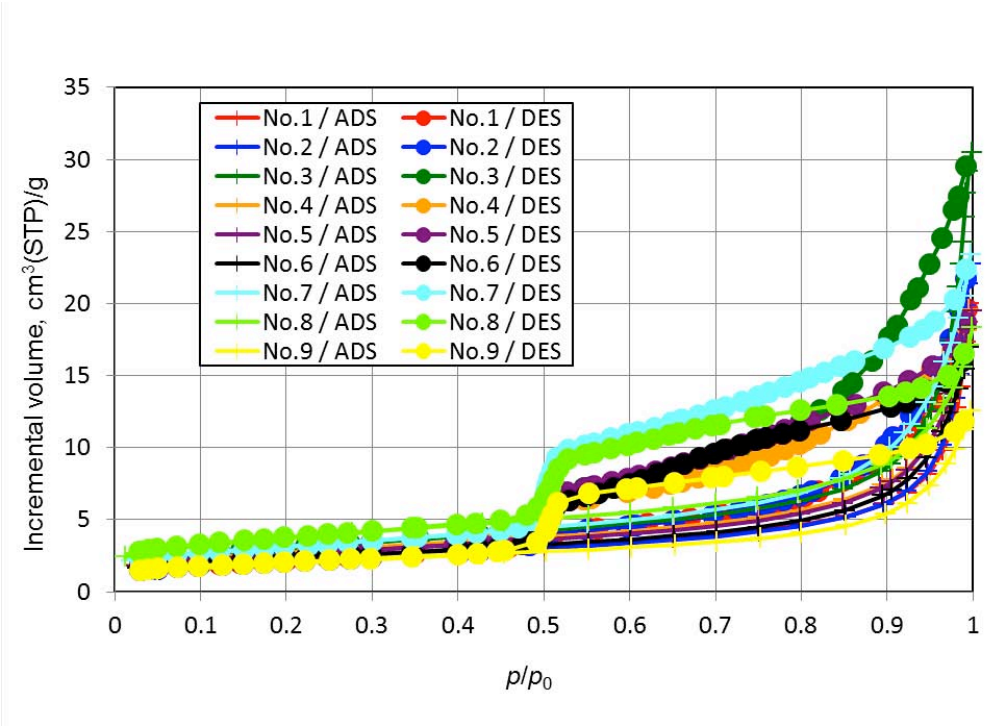

Fig.3 Adsorption and desorption isotherm.

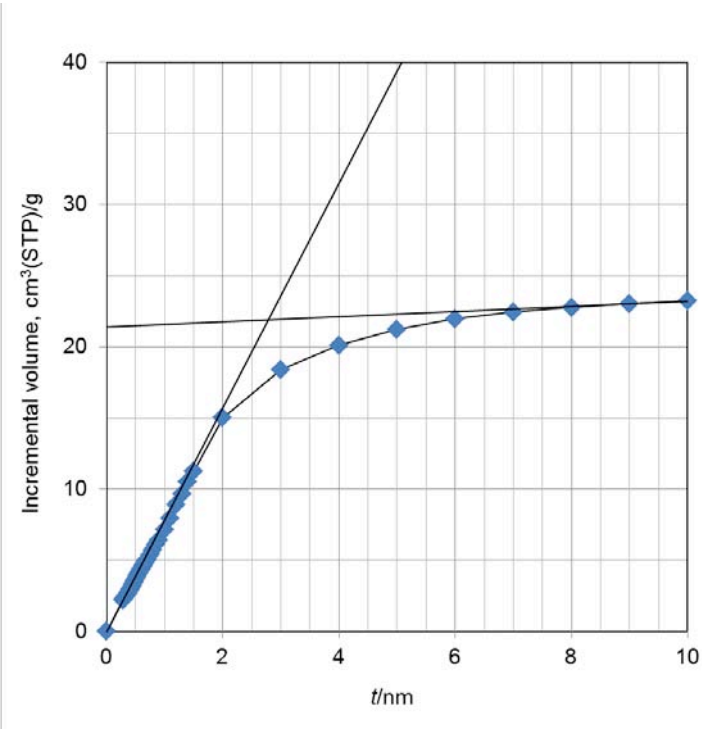

Fig.4 t-plot (Core No. 7).

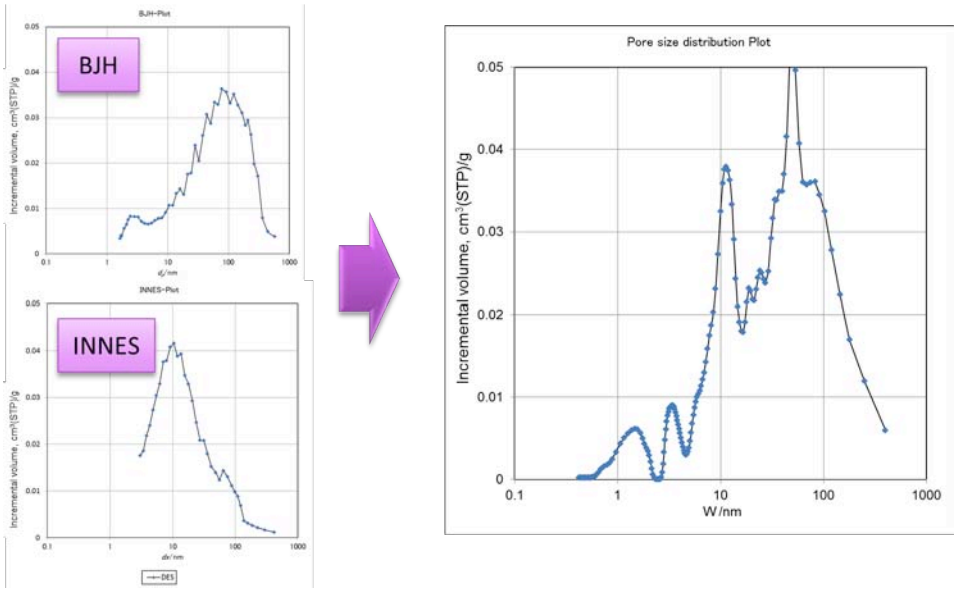

Fig.5 Pore size distribution from BJH and INNES.

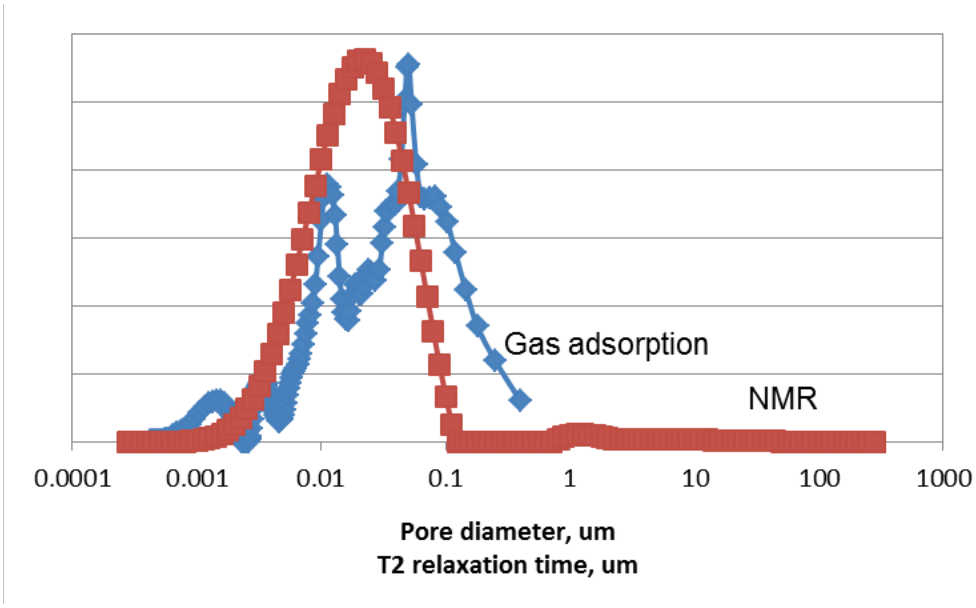

Fig.6 Pore size distribution from BJH and INNES.