

NMR Measurement and Analysis of Porosity and Permeability for Hydrate-bearing Sediments

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ABSTRACT

In-situ observation of gas hydrate formation and dissociation in hydrate-bearing sediments, and water-permeability measurements for the sediments have been performed by the apparatus combined proton nuclear magnetic resonance (^1H NMR) and permeability measurement system, which we had originally designed. As a result of NMR measurement and analysis, it was found that hydrate growth make apparent pore size gradually smaller. On the other hand, hydrate dissociation is supposed to advance from water-hydrate interfaces, where apparent pore size becomes larger gradually. All the sediments used here have the same tendency of decreasing pore-size with changing water saturation due to hydrate formation and growth. NMR measurement for gas hydrate sediments has a great possibility in understanding the structure of pore spaces and the change in porosity and permeability during exploration and production stages.

KEY WORDS: NMR, permeability, porosity, gas hydrates, sediment, formation and dissociation

INTRODUCTION

The remarkable technology of nuclear magnetic resonance (NMR) logging has improved continually. Many cases of Geophysical exploration in oil and gas production have adopted NMR logging tools for evaluating reservoir parameters and for assessing formation productivity. The application of NMR technique to the evaluation for gas hydrate-bearing sediments was reported by Kleinberg (2003a, 2003b). In this study, the possibility of the estimation of permeability and porosity in the formation process of gas hydrates (GH) was firstly examined, and obtained a good correlation between experiment and NMR analysis. Recently, Minagawa et al. (2008) published his original article to J. Geophysical Research on the improvement of NMR measurement and a novel technique of analysis for estimating the permeability change in the process of hydrate dissociation.

This paper presents a NMR methodology for the estimation of permeability change in both processes of GH formation and

dissociation in sandy sediments. The NMR measurements were performed in the experiments using high pressure cells and sediments, in order to make clear the hydrate behavior in porous media and pore space. The improvement of permeability and porosity estimation in core samples of gas hydrates was also investigated to be able to introduce for practical use in gas hydrate exploration.

PERMEABILITY ESTIMATION USING NMR MEASUREMENT

Permeability governs the movement of fluids, gas and liquid, through pore spaces and networks in porous media, such as hydrate-bearing sediments. Applications include enhancement of oil and natural gas recovery, management of water resources, CO_2 geological storage, geothermal energy extraction and strategies for safe design of radioactive waste repositories. It is an elusive parameter in various kinds of reservoirs as it is very difficult to determine directly using current sub-surface logging technology. It is a complex interplay of porosity, pore connectivity, grain packing, grain size, rock electrical properties and permeabilities. From these data, the empirical equations of Kozeny-Carmen are popularly used in the oil and gas industry to calculate permeability. Nelson (1994) suitably divided these into (i) surface area (e.g., Coates et al., 1991), (ii) pore size (e.g., Swanson, 1981) and (iii) grain size (e.g., Berg 1970; Basan et al., 1996) models.

NMR measurement gives us useful information on the relaxation time function of proton (^1H) through pore networks, based on an important parameter of T_2 that is called as transverse relaxation time. The intensity of T_2 distribution is proportional to the number of protons of water and hydrocarbon (methane) in pore space. Decreasing intensity means the consumption of water and methane to form GH, and the shorter peak-top T_2 indicates smaller apparent pore size, in which GH was assumed to be solid material as well as sand grain. These changes are thought to indicate that MH growth make apparent pore size gradually smaller. On the other hand, GH dissociation is supposed to advance from water-hydrate interfaces, where apparent pore size becomes larger gradually. On the other hand, MH dissociation is supposed to advance from water-hydrate interfaces, where apparent pore size becomes larger gradually. T_2 values are analyzed using the methodology of CPMG, as shown in Figure 1, based on spin-echo