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Electrical and geomechanical Properties of Natural Gas Hydrate-bearing Sediments from Ulleung Basin, East Sea, Korea

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ABSTRACT

Gas hydrates are widespread, occurring in both permafrost sediments and deep marine sediments on the world's continental margins. The large amounts of gas hydrate reserves suggest the potential of gas hydrates as an energy resource if economically viable production methods were developed. The geomechanical property evolutions of gas hydrate-bearing sediments during gas production from gas hydrate deposits are crucial for the efficient and safe gas production from gas hydrate deposits.

The lab-scale production tests results reported here used GHOBS experimental system with natural gas hydrate-bearing sediments recovered from the Ulleung Basin, East Sea, Korea. The electrical property evolution during consolidation and production using various techniques are monitored and compared together with geomechanical properties and production recoveries.

The mechanical behavior of hydrate-bearing sediments depends on hydrate saturations, hydrate occurrences, soil fabrics, absolute and relative permeability, and overburden pressure. The electrical property monitoring enables monitoring of volume fractions and locus of pore fluids and hydrates and enhances the understanding of mechanical behavior.

1. INTRODUCTION

Gas hydrates consist of guest gas molecules inside hydrogen-bonded water lattices. Methane is the most common guest molecule, and gas hydrates are stable at low temperature and high pressure condition. Gas hydrates are widespread, occurring in both permafrost sediments and deep marine sediments on the world's continental margins where the pressure and temperature conditions meet the gas hydrate equilibrium conditions. The large amounts of gas hydrate reserves suggest the potential of gas hydrates as an energy resource if economically viable production methods were developed. The proper understandings of mechanical behavior of gas hydrate-bearing

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sediments during gas production from gas hydrate deposits are crucial for the efficient and safe gas production from gas hydrate deposits. Gas production from gas hydrate deposits involves the dissociation of gas hydrate, inducing phase transformation from solid gas hydrate to liquid gas and water, which may provoke significant changes in sediment properties, loss of integrity for boreholes, and possibly regional subsidence of ground surface. Previous studies have explored electrical and mechanical properties without pore volume expansion induced by gas volume produced from gas hydrate dissociation (Lee 2008, Lee 2010a, Lee 2010b). In this study, the effect of gas phase on electrical property and gas volume expansion on mechanical property are additionally explored using natural hydrate-bearing sediments, and the results are compared with previous experimental study results.

2. EXPERIMENT DESIGN

The presence of natural gas hydrates has been confirmed during the Ulleung Basin Gas Hydrate Expedition 1 (UBGH1) in 2007. Natural hydrate-bearing sediments retrieved from the Ulleung Basin, East sea, Korea during UBGH1 have been used in this study. The Ulleung Basin is located in southwestern part of the East Sea, Korea and is a deep, bowl-shaped and back-arc basin. The water depth of the basin ranges from 1500 to 2300 m.

UBGH1 drilling expedition drilled three sites as shown in Fig. 1, and cores retrieved from UBGH1-9 (96~98 mbsf) and UBGH1-10 (84~86mbsf) have been used in this study. The site UBGH1-9 has a water depth of 2099 m below sea level and the BGHS at 182 mbsf. Gas hydrates occurred in silty and/or sandy layers between 63 and 151 mbsf. The site UBGH1-10 has a water depth of 2077 m below sea level and the BGHS at 163 mbsf. Gas hydrates occurred between the seafloor and 141 mbsf in sand and ash layers. Specimens have been retrieved with pressure corers, scanned with P-CAT system, depressurized quickly, and stored in a container with liquid nitrogen.

An experimental device (GHOBS I – Gas Hydrate Ocean Bottom Simulator I) that can accommodate pressure core samples sub-sampled from pressure cores under pressure is used in this study. GHOBS I can characterize the physical properties of GH-bearing sediments and the behavior of GH-bearing sediments during GH production under different stress conditions, hydrate saturations, and sediment types and structures (Fig. 2). The device can apply 20 MPa of fluid pressure and 5MPa of vertical effective stress, which are the typical ranges of stress condition in deep sea sediments. The cell body is built with aluminum alloy so that the specimen can be scanned by X-ray CT system. The top and bottom plate of the cell houses sensors for vertical strain, elastic-wave velocity, electrical resistivity, pressure, and temperature. Cell temperature is manually controlled with cooler and pressures including pore-fluid pressure and vertical effective stress are controlled by programmable syringe pumps. Wet test meter is used for recovery rate measurement during production test.

The pressure core samples have been stored in pressure storage chamber onboard and cut and transferred to GHOBS I under in-situ fluid pressure condition. The in-situ vertical effective stress condition is retained by consolidating a specimen to in-situ vertical effective stress in three incremental loading steps. After the specimen is fully consolidated in the in-situ vertical effective stress, depressurization is applied to a specimen.

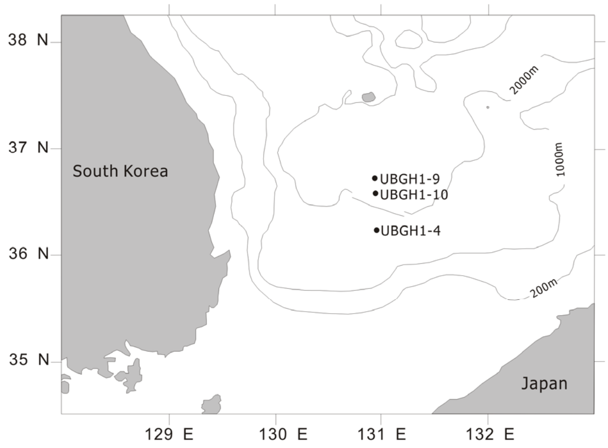

Fig. 1 Site map of study area

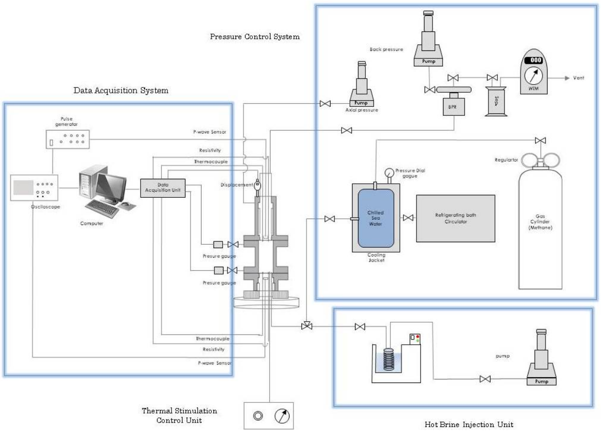

Fig. 2 Schematic diagram of GHOBS I system

3. RESULTS AND DISCUSSIONS

A typical evolution of void ratio and electrical resistivity during the experiment is shown in Fig. 3. This low void ratio is probably due to high bio-origin particles with internal pore structures. The compression indices calculated range from 0.4 to 0.9. Electrical resistivity is higher than those from Lee 2010b since the sediments have salty pore water in this study. During production, a few reactions affect the electrical resistivity. Solid hydrate becomes electrolytes and gas where electrolytes decrease resistivity and gas increases resistivity. The ionic concentrations of electrolytes also control the electrical resistivity after hydrate dissociations. Overall, the gas phase formation seems to compensate other phenomena and results in the resistivity increase after hydrate dissociation.

Electrical resistivity change before and after hydrate dissociation are plotted in Fig. 4 with previous results without gas expansion effect (Lee 2010b). In the previous study, THF was used as hydrate former, and the effect of gas phase and ionic concentration was not considered, which give resistivity decrease after hydrate dissociation due to the increase in the water fraction. This study gives resistivity increase after hydrate dissociation because the gas phase appears. The absolute magnitude of values and changes are lower than those from previous study since specimens in this study have brine as pore water.

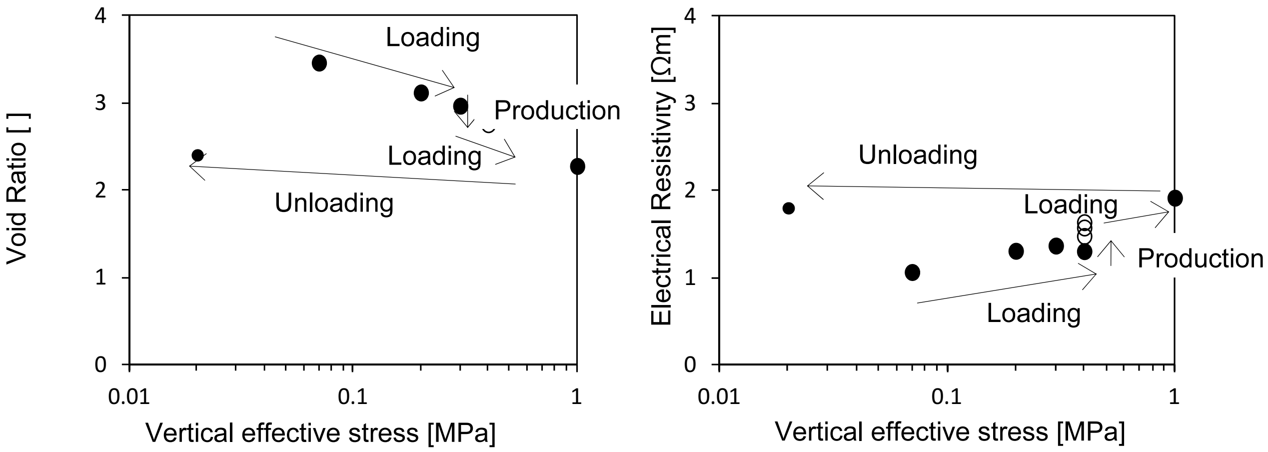

Fig. 3 The void ratio and the electrical resistivity during the whole experimental sequence

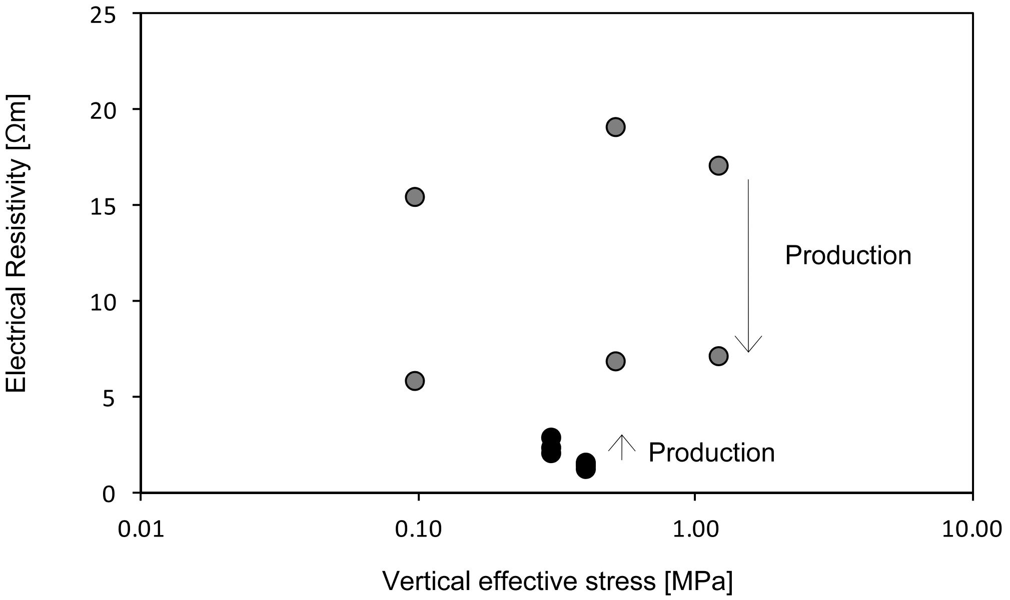

Fig. 4 The electrical resistivity change upon hydrate dissociation. Gray dots are results from previous study without the effect of gases (Lee 2010b). Black dots are the results from this study

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