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Geotechnical properties of deep oceanic sediments recovered from the hydrate occurrence regions in the Ulleung Basin, East Sea, offshore Korea

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ABSTRACT

This study presents comprehensive geotechnical data of the natural marine sediments cored from the hydrate occurrence regions during the Ulleung Basin Gas Hydrate Expedition 1 (UBGH1), East Sea, offshore Korea in 2007. Geotechnical soil index properties of the Ulleung Basin sediments, including grain size distribution, porosity, water content, Atterberg limits, specific gravity, and specific surface area, were experimentally determined. These soil index properties were correlated to geotechnical engineering parameters (e.g., shear strength and friction angle) by using well-known empirical relationships. By performing standard consolidation tests on both undisturbed specimens (as recovered from the original core liner after hydrate dissociation) and remolded specimens, stress-dependent mechanical and hydraulic properties (e.g., compressibility and hydraulic conductivity) were measured. The experimental results provide important engineering parameters, and demonstrate the effect of hydrate presence and consequential dissociation to index properties, engineering parameters, and innate sediment structures.

1. Introduction

Gas hydrate is a solid compound in which a gas molecule is caged within a solid lattice of water molecules. Methane hydrate, the most common type occurring in nature, is found in both permafrost sediments to depth of ~1 km and deep marine sediments at water depth more than ~500 m, extending to 500–700 m below the seafloor. The vast amounts of gas hydrate reserves have drawn scientific attentions as a potential energy resource. However, gas production from gas hydrate deposits requires different knowledge and technologies from conventional gas production because the decomposition of solid gas hydrate to gas and water invokes complex physical, chemical and mechanical interactions in hydrate-bearing sediments, posing significant challenges in developing safe and effective production technology.

Physical and geotechnical properties of hydrate-bearing sediments, such as compressibility, permeability, undrained shear strength, and index properties, are key factors for assessing productivity and safety issues of gas production from hydrate-bearing deposits (gas hydrate production), and those are used as essential input parameters for numerical simulations of gas hydrate production. Accordingly, many efforts have been focused on characterizing natural sediments with or without natural gas hydrates (e.g., Winters et al., 1999; Francisca et al., 2005; Yun et al., 2006), and identifying the impact of hydrate presence on various sediment properties with either synthetic or natural hydrates (e.g., Hyodo et al., 2007; Kneafsey et al., 2008; Lee et al., 2008, 2010a, 2010b; Suzuki et al., 2008; Daigle and Dugan, 2009; Lee et al., 2009; Kwon and Cho, 2009; Lee et al., 2010c).

Since the presence of natural gas hydrates has been confirmed during the Ulleung Basin Gas Hydrate Expedition 1 (UBGH1) in 2007 (e.g., Park et al., 2008; Bahk et al., 2009; Kim et al., 2010), in this study, we performed various laboratory experiments on the sediment cores recovered from the hydrate occurrence regions during the UBGH1 in the Ulleung Basin, East Sea, offshore Korea. A database for the soil index properties and geotechnical parameters of the core samples was complied, and the effect of hydrate presence and consequential dissociation on index properties, engineering parameters, and innate sediment structures were discussed.

2. Sites of interest

The East Sea is a marginal sea that is connected to the North Pacific Ocean, the Sea of Okhotsk, and the East China Sea (Chough

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et al., 2000). It consists of three deep basins: the Ulleung Basin, Yamato Basin, and East Sea Basin (Japan Basin). The Ulleung Basin, located in southwestern part of the East Sea, is a deep, bowl-shaped and back-arc basin. The Ulleung Basin is semi-enclosed by the continental margin of the Korean Peninsula to the west and by the rugged Korea Plateau to the north. In the east and south, the basin is bounded by the gentle slope and broad shelf of the Japanese Arc and the Oki Bank (Bahk et al., 2000; Cha et al., 2007). The water depth of the basin ranges from 1500 to 2300 m and gradually deepens toward the Ulleung Interplain Gap (to a maximum of 2400–3200 m of water depth; Lee and Kim, 2002).

Three sites, UBGH1-4, UBGH1-9, and UBGH1-10, were chosen for drilling sites during the 2007 UBGH1 hydrate drilling expedition, in the Ulleung Basin, East Sea, Korea (see Fig. 1). The site UBGH1-4, located at 36.268°N, 130.906°E, has a water depth of 1841 m below sea level and the base of gas hydrate stability (BGHS) at 196 m below the seafloor (mbsf). Gas hydrates occurred in thin coarse-grained sediment layers between 185 and 196 mbsf. The site UBGH1-9, located at 36.714°N, 130.900°E, 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, and this interval coincides with the high resistivity zone of the LWD data. The site UBGH1-10 is located at 36.6355°N, 130.900°E, and 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. Sediment cores were retrieved from those three sites.

3. Description of sediment sample

Natural marine sediment samples were retrieved using conventional Fugro Hydraulic Piston Corer (FHPC), Fugro Corer (FC), Fugro Rotary Pressure Corer (FRPC) and Fugro Pressure Corer (FPC) from four boreholes (UBGH1-4B, UBGH1-4C, UBGH1-9C, and UBGH1-10B) at three sites in the Ulleung Basin. Most of cores have been recovered by FHPC and only two cores have been recovered by FC. Ten cores have been recovered by FRPC and another ten cores have been recovered by FPC. Fugro Hydraulic Piston Corer is designed to accommodate highly expansive sediments and is known to have higher recovery rates and less sample disturbance than other coring systems (Fugro, 2002). Fugro Pressure Corer adopts hydraulic percussion driving system, and recovered core samples are usually less disturbed than Fugro Rotary Pressure Corer that adopts water-driven rotary motor driving system. Most of sediments samples in this study are from cores recovered by FHPC, and a few samples are from those recovered by FRPC and FPC. The hole-core-section numbers and their corresponding depths are summarized in Table 1 (UBGH1-4), Table 2 (UBGH1-9), and Table 3 (UBGH1-10).

Both undisturbed and disturbed samples were used in this study. *Undisturbed samples* were retrieved with conventional corers, cut in 5 cm length, and preserved in the original core liners. *Disturbed samples* were retrieved with both conventional piston corers and pressure corers. The disturbed samples from the piston corers were collected from the remained sediments after preparing specimens for pore water geochemistry tests while those from the pressure corers were obtained after on-board depressurization tests.

For notation of hole-core-section numbers in Tables 1–3, the first two characters indicate the hole name, and the number after the dash indicates the recovered core number followed by the coring method (i.e., H: Fugro Hydraulic Piston Corer, R: Fugro Rotary Pressure Corer, P: Fugro Pressure Corer). The last two characters represent the successive round sections in a given core. All core samples were tested to determine soil index properties. Some core samples including undisturbed core samples were selected for consolidation tests to determine the compressibility and permeability of sediments.

4. Soil index properties

Sediment grain and pore fluid characteristics have profound effects on the morphology, extent, and growth characteristics of natural gas hydrate (Winters et al., 1999); and these characteristics

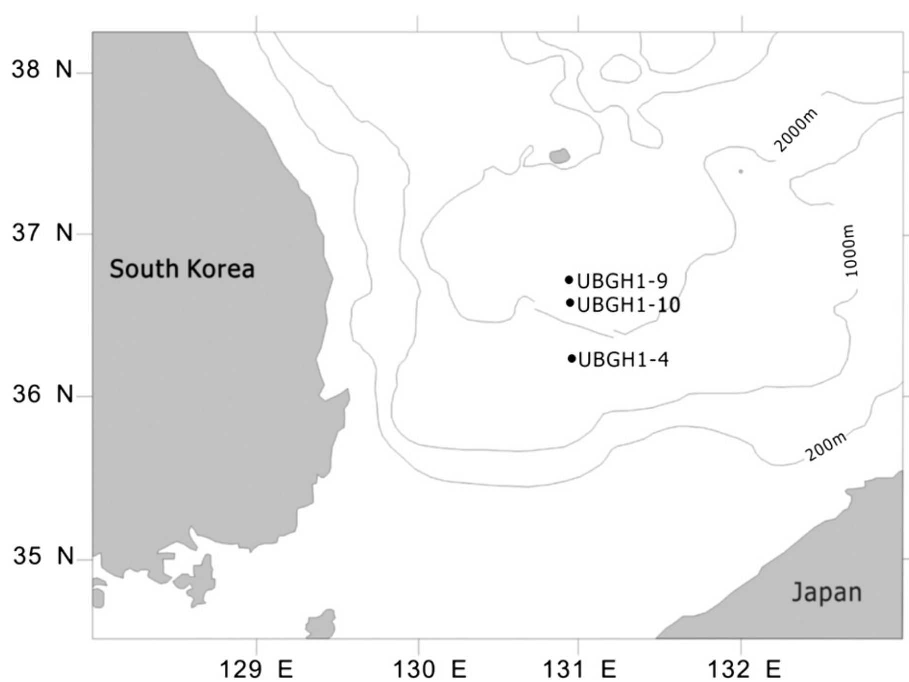

Figure 1. Location of the study sites in the Ulleung Basin, East Sea.