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Petrophysical and geomechanical properties of gas hydrate-bearing sediments recovered from Alaska North Slope 2018 Hydrate-01 Stratigraphic Test Well

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Extended Abstract

Knowledge of petrophysical and geomechanical properties of gas hydrate-bearing sediments is essential for predicting reservoir responses to gas production. The same information is also needed for designing production well completions such as specifications for artificial lift, test site water storage capacity, and mesh size for the sand control systems. In December 2018, the Stratigraphic Test Well Hydrate-01 was drilled in the western part of the Prudhoe Bay Unit on the Alaska North Slope as part of the technical planning effort for a future long-term production test being planned and led by a collaborative team from the U.S. Department of Energy - National Energy Technology Laboratory, U.S. Geological Survey, and Japan's Research and Development Consortium for Pore Filling Hydrate in Sand (MH21-S) (Boswell et al., 2020, Collett et al., 2020, Okinaka et al., 2020). Logging-while-drilling (LWD) data were acquired (Haines et al., 2020) and sidewall core sampling depths were selected from the LWD logs. Sidewall pressure coring was conducted to recover gas hydrate-bearing sediments from two reservoir sections within Unit B and Unit D. A total of 34 cores were successfully recovered by five runs of a wireline deployed pressure coring system (CoreVault® System - Halliburton). The core analysis plan for this project is shown in Figure 1. Upon recovery, the pressure core autoclaves were transported from the Alaska North Slope to the Stratum Reservoir laboratory in Anchorage Alaska. To access the cores, they were first quenched in liquid nitrogen while still at high pressure in the core system autoclaves (Figure 1a). The cores were next removed from the pressure corer autoclaves with temperature control support from dry ice and stored under liquid nitrogen at atmospheric pressure. A total of 17 disturbed low-quality cores were processed for index property measurements, which included grain size and grain density analysis. Another four core samples were depressurized, trimmed, and core plugs were cut from each core and used to measure intrinsic permeabilities of host sediments (Figure 1). Unsteady-state permeability measurements were conducted on two samples to obtain relative water permeability to gas, and core scale Nuclear Magnetic Resonance (NMR) transverse relaxation time (T2) distribution measurements were performed to evaluate pore size distribution (Figure 1b). A total of 13 remaining high-quality cores with significant gas hydrate concentrations were preserved for advanced laboratory analysis. The National Institute of Advanced Industrial Science and Technology, as a part of MH21-S Project, received the 13 remaining high-quality core samples at their laboratories in Sapporo, Japan for advanced core analysis. High-resolution X-ray computed tomography (X-CT) was used to analyze the physical characteristics of the samples, which showed for the most part undisturbed lithological layers. Cores were lathed into cylindrical shapes and prepared for multi-property measurements (Figure 1c). As a result, sediment from the reservoir section of Unit D was characterized as silty-sand at ~37% porosity with ~80% gas hydrate saturation. An average hydration number n = 6.16 was measured for the recovered gas hydrate samples by Raman spectroscopy. An average intrinsic permeability of ~400 mD and in situ effective permeability (with hydrate) on the order of ~10 mD was measured for a total of five core samples. The recovered cores from the reservoir section of Unit B consisted of well-sorted sand at ~40% porosity with ~95% gas hydrate saturation. An average intrinsic permeability of ~1 Darcy and in situ effective permeability on the order of ~30 mD was measured for the Unit B reservoir section cores. Additional laboratory measurements yielded small permeability reductions due to porosity loss with increasing effective stress that simulated sediment consolidation along with depressurization in the

highly permeable sandy sediment. The apparent limited change in porosity and permeability may be caused by the low compressibility of quartz sand grains in the recovered cores. X-ray diffraction (XRD) and thermal conductivity analysis also indicated a high quartz content within the recovered cores. Completed triaxial compression tests established internal friction angles based on the Mohr-Coulomb's failure criterion, which were calculated at 40° for hydrate-bearing sediment and 29.8° for hydrate free sediment.

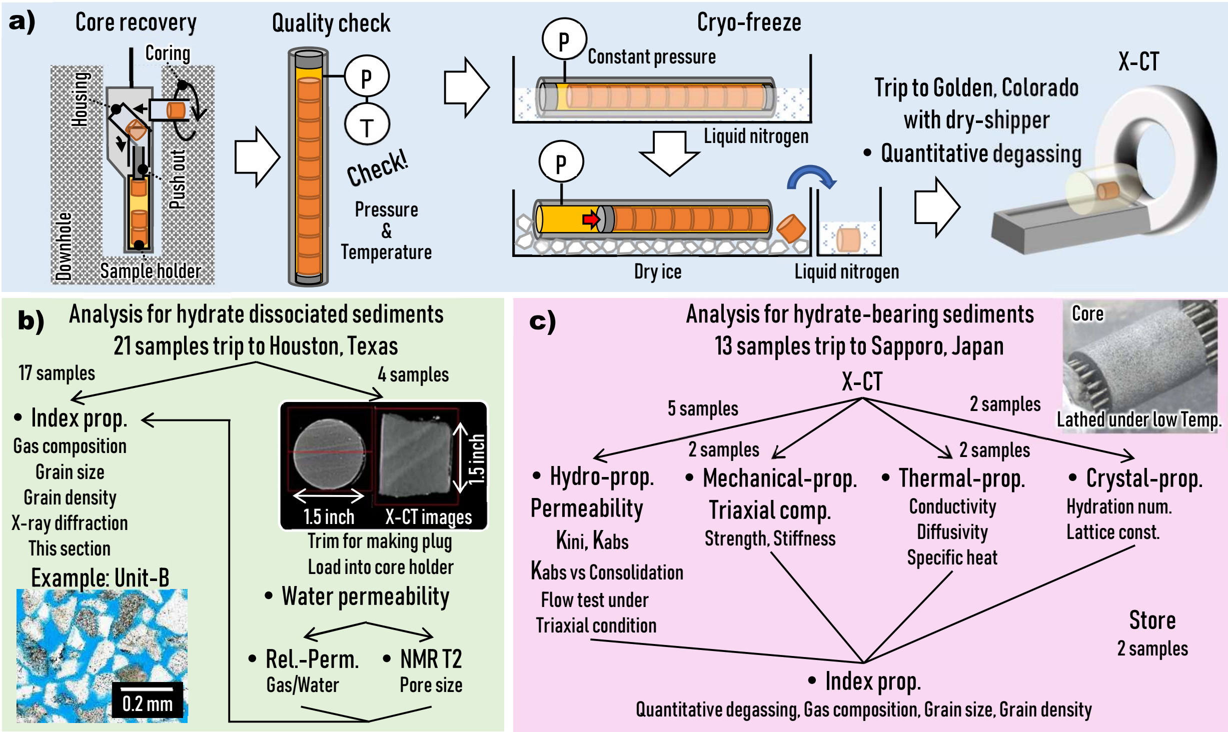

Figure 1: Core analysis plan for sidewall pressure cores as recovered from the Hydrate-01 well. a) Core recovery, treatment, and transfer from Prudhoe Bay to Golden, Colorado via Anchorage, Alaska. b) Degassed sediment core analysis performed by Stratum Reservoir at Houston, Texas. c) Hydrate-bearing sediment core analysis scheme as performed by National Institute of Advanced Industrial Science and Technology in Sapporo, Japan. Kabs = Permeability absolute, Kini = Permeability intrinsic, NMR T2 = Nuclear magnetic resonance transverse relaxation times, Rel.-Perm. = Relative permeability, X-CT = X-ray computed tomography scanning

Keywords: Pressure core, side wall coring, permeability, strength, hydration number, thermal conductivity.

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