Marine and Petroleum Geology 66 (2015) 388–395

Contents lists available at ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Research paper

Density structure report from logging-while-drilling data and core data at the first offshore gas production test site on Daini-Atsumi Knoll around eastern Nankai Trough

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A R T I C L E I N F O

Article history:
Received 24 September 2014
Received in revised form
12 February 2015
Accepted 16 February 2015
Available online 5 March 2015

Keywords:
Density log
Borehole enlargement
Caliper log
Logging-while-drilling (LWD)
Pressure core
Mercury injection porosity

A B S T R A C T

The permeability of methane hydrate sediments is controlled by the lithology of the sediments and the saturation of methane hydrate in pore spaces. Thus, estimates of porosity in the reservoir are important. However, sediments in gas hydrate reservoirs are soft; thus, disturbances during drilling easily degrade the quality of data, despite the sediment-reinforcing effects of gas-hydrate crystals. Hence, methods for correcting the measured properties of sediments are quite important.

In this study, we obtain the density (porosity) structure of sediments within and above the methane hydrate reservoir. Due to uncertainties in the density logs, we corrected the logs using borehole caliper data, which is sometimes negatively correlated with density. The corrected density data agreed well with results inferred from analysis of sediments recovered in pressure cores. On these samples, we conducted mercury injection porosimetry on frozen depressurized samples from 2004 to 2012 and also determined density from the onboard multisensor core logger (MSCL) data on conventional cores, especially in methane hydrate concentrated zone (MHCZ). Our results allow us to divide the sediments above the gas hydrate stability zone (GHSZ) on Daini-Atsumi Knoll into four zones. The zone boundaries correspond to facies boundaries. This implies that the sedimentary facies strongly influenced not only the lithology, but also physical properties such as density (porosity).

1. Introduction

Dissociation of methane hydrates (MH) in sediments during depressurization is governed by the permeability of the sediments, which is generally controlled by lithology. Thus, lithology and permeability are important for constructing models for reservoir simulations. Additionally, to build reliable models of deformation during depressurization, an understanding of the properties of both the sediments and any pre-existing deformation structures in the sediments is necessary. In MH-bearing sediments, permeability is also controlled by MH saturation, which is the ratio of MH-occupied pore volume to the total pore volume of the sediments. Thus, if the estimated porosity is incorrect, both the MH saturation and permeability could be incorrect. Therefore, assessing porosity and bulk density of sediments provides important information for the analysis of MH reservoir sediments.

In this paper, we derive sediment densities for the MH reservoir at the Daini-Atsumi Knoll using cores obtained in 2004 and 2012 (Fig. 1). We use in situ borehole data from logging-while-drilling (LWD) and analyses conducted on pressure cores and on depressurized samples.

2. Methods

A number of cores were retrieved from the methane hydrate concentrated zone (MHCZ) at the A1-SC well of the 2004 coring campaign (Takahashi and Tsuji, 2005; Tsuji et al., 2009; Fujii et al., 2009; Komatsu et al., 2015) and the AT1-C well of the 2012 coring campaign (e.g., Yamamoto et al., 2012; Inada and Yamamoto, 2015; Suzuki et al., 2015).

Abbreviations: TNP, Thermal-neutron porosity; NGD, Neutron-gamma density; DP, Density porosity; MD, Measured density; DD1, Density difference between MD and Line1; DD2, Density difference between MD and Line2; DDc1, Calculated density difference from DD1 distribution shown in Figure 5a; DDc2, Calculated density difference from DD2 distribution shown in Figure 5b.

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http://dx.doi.org/10.1016/j.marpetgeo.2015.02.026
0264-8172/

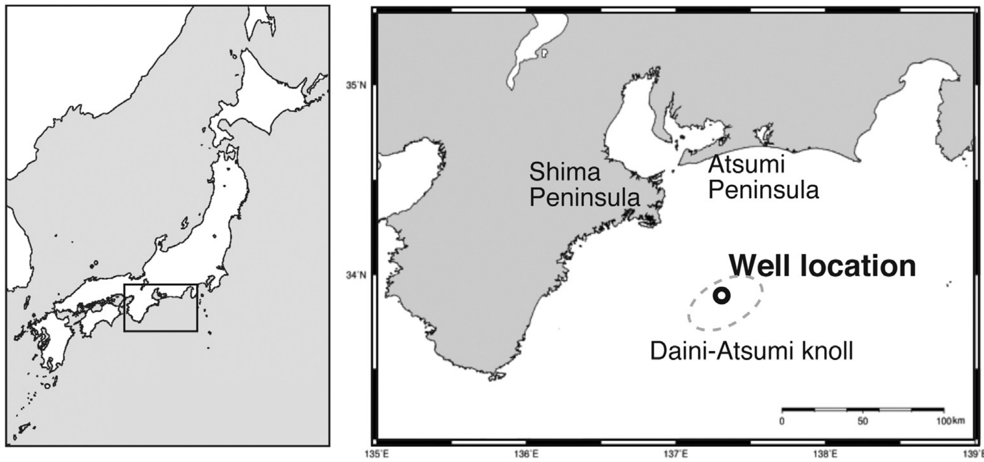

Figure 1. Location of wells for this study.

Multisensor core logger (MSCL) measurements (e.g., Suzuki et al., 2015) were carried out on conventional core aboard the D/V *Chikyu* at the time of the coring campaign by personnel of Marine Works Japan Ltd. (Table 1). The MSCL includes a sensor to measure the attenuation of gamma rays and determine the gamma density of sediment.

Bulk density can be calculated from water content and grain density when sample volume is taken into account. Researchers measured the properties of the sediments (e.g. Konno et al., 2015a,b; Yoneda et al., 2015a, 2015b; Ito et al., 2015; Egawa et al., 2015). The samples were subsampled from pressure cores that were taken rapidly depressurized and quenched with Liquid Nitrogen. During these measurements, bulk densities and/or porosities were calculated from the sample pieces. The samples in Table 2 might be influenced by those pressure and temperature changes; however, values of sample densities that did not take damage were plotted in Figure 3.

A mercury-injection porosimeter can directly measure sample porosity, and the bulk density can be calculated when grain density is known. Mercury injection porosities and grain densities were measured at the AIST laboratory using freeze-dried pieces subsampled from frozen, depressurized pressure cores recovered from A1-SC location during the 2004 coring campaign. These cores were taken 150 m distant from the AT1-C borehole drilled for in 2012 (Table 3). A PoreMaster-60GT© and an Accupyc1330© Pycnometer were used for measurements.

3. Results

Based on porosities inferred from LWD data, we concluded that values of both the thermal neutron porosities (TNP) and the density porosities (DP) computed from the neutron–gamma densities (NGD) were too high for the reservoir sediments. Having already analyzed core samples from 2004, we were aware that the medians of porosity distribution and grain density were approximately 43% and 2.698 g/m^3, respectively.

The quality of all types of cores degrades after retrieval. However, the pressure cores, retrieved at close to in situ hydrostatic pressure, were rapidly depressurized and flash-frozen with liquid nitrogen prior to the porosity measurements and largely retain their porosity structure (Konno et al., 2015a,b). The frozen rapidly-depressurized pressure cores obtained in 2004 were usable for mercury injection porosity, which has relatively high accuracy

Table 1
Multisensor core logger data.

C8002A		
Depth [mbsf]	Porosity [–]	Density [g/cm^3]
1.8	0.57	1.74
3.5	0.46	1.92
9.0	0.58	1.74
15.3	0.46	1.96
C8002B		
Depth [mbsf]	Porosity [–]	Density [g/cm^3]
17.4	0.59	1.65
20.6	0.57	1.70
23.1	0.55	1.74
26.0	0.46	1.95
27.8	0.59	1.73
30.7	0.52	1.79
32.7	0.51	1.88
39.9	0.52	1.80
40.6	0.54	1.78
40.6	0.48	1.97
41.3	0.58	1.75
41.7	0.57	1.73
42.3	0.58	1.72
42.7	0.44	1.99
43.7	0.55	1.71
45.1	0.53	1.80
52.1	0.52	1.81
54.7	0.50	1.83
54.7	0.44	1.98
54.7	0.44	1.96
55.0	0.53	1.84
63.7	0.45	1.90
65.2	0.47	1.89
71.0	0.58	1.72
73.4	0.40	1.96
74.0	0.53	1.80
81.7	0.54	1.79
82.7	0.52	1.79
83.9	0.37	2.06
84.2	0.40	2.02
91.8	0.42	1.99
92.9	0.51	1.80
94.1	0.43	2.05
C8002A		
Depth [mbsf]	Porosity [–]	Density [g/cm^3]
1.9	0.60	1.75
3.5	0.64	1.60

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