Supplementary Materials: Gas-In-Place Estimate for Potential Gas Hydrate Concentrated Zone in the Kumano Basin, Nankai Trough Forearc, Japan

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Table S1. Summary Table of Data from Site C0009 and C0002.

Data Type	C0002	C0009 (20 km NE of Site C0002)
IODP Expeditions	314, 315, 332, 338, 348 Twelve boreholes: A, B, C, D, F, H, J, K, L, M, N, P	319
Seafloor Depth	1936 mbsl	2054 mbsl
Bottom Water Temperature	2°C	2°C
BSR Depth	~389 mbsf	No BSR is imaged at C0009
Heat Flow	57 mW/m2 [58]	39 mW/m2 [77] (assumed)
Geochemical		
Sulfate Methane Transition Zone	~9 mbsf	-
Cl-	Discrete, negative Cl- excursions documented between ~125 mbsf to 400 mbsf with the lowest measured value of 136.5 mM at the BSR depth (389 mbsf) [26]. The Na+ and Cl- baseline decreases with depth until it reaches a minimum at the BSR then increases with depth until returning to seawater values at ~800 mbsf. We propose that this profile indicates baseline freshening from clay mineral dewatering or an episodic fluid expulsion event. The discrete negative Cl- excursions intervals can confidently be attributed to pore fluid freshening from gas hydrate dissociation [59].	-
TOC (Important limiting factor of GH precipitation [45])	Measured below 200 mbsf only during 338. TOC ranged from 0.21 – 0.97 wt% peaking at 800 mbsf, with an average value of ~ 0.58 wt% [26]. Woody material was discovered in the lower basin sequences which is very thin at C0002, but thickens at C0009. NH_4^+ concentration was high at Site C0002 suggesting organic matter degradation is active [105].	TOC from cuttings collected between 1038 and 1588 mMSF and from core samples collected from 1509.8 to 1591.5 mCSF. No data exist for upper basin sediments. TOC was on average 2.51 wt% in comparison to 0.55 avg. wt% at C0002. Notably, TOC content reached peaks as high as 8.7 wt% at 1088 and 1183 MSF likely from high wood and coal (lignite) content in the lower forearc sediments [40]. This is sufficient for hydrocarbon production of natural gas *in situ* and thus, we could consider this zone a source region. However the geothermal gradient at C0009 is lower than at C0002, and the temperature here is <40°C at 1200

		mbsf which is not high enough for *in situ* thermal cracking [57]
Gas (Headspace and void)	High SO_4^{2-} concentrations were detected between 200 and 500 mbsf. There is no evidence from other chemical profiles to suggest contamination. CH_4 concentrations in headspace gas range from nearly 0 to 50,000 ppm with high variability downhole. Peaks occur at 30 mbsf, and are clustered between 250 mbsf to 450 mbsf, with deeper peaks at 920 mbsf and 1050 mbsf. Higher molecular weight hydrocarbons, including pentane and ethane, were found in low concentrations with ethane peaks between 390-400 mbsf, at 920 mbsf and at 1050 mbsf. Expedition 338 scientists noted that ethane concentrations are affected by extraction methods [26]. Pentane peaks occur at 200 mbsf and 380 mbsf (within the GHSZ). Despite the presence of ethane and pentane within the GHSZ, isotopic analysis of $\delta^{18}C$ of CH_4 determined that the gas had microbial origins [26]. The $\delta^{13}C$ of CH_4 ratio is most enriched at -50‰ at 500 mbsf and becomes more depleted with depth down to 60‰ [105]. Thermogenic gas is prevalent below 1700 mbsf with C_1/C_2 ratios between 300 and 400 [91]. Void space gas measurements were richer in methane than headspace gas measurements. Void gas samples tend to capture the more volatile components which are dissolved in interstitial waters (methane less soluble than ethane), compared to headspace measurements which tend to be enriched in less volatile components and reflect the gas composition within sediments.	Mud gas samples were collected during all phases of drilling and analyzed throughout the hole. CH_4 concentrations were high in the lower forearc basin sediments (791-1285 mbsf) reaching up to 14 vol% [40]. Higher order hydrocarbons including ethane (C_2H_6) and pentane (C_3H_8) were also detected at 16 ppmv and 3 ppmv respectively [40; 57].
Borehole		
LWD	Continuous log from the seafloor to 1400 mbsf at resolution of 1 sample/4 cm. Both Expedition 314 and 338 detected a significant gas hydrate bearing zone (Zone A) and gas bearing zone (Zone B) at analogous depths [26, 77, 59] Expedition 338, Hole C0002F Zone A is 218.1 to 400.4 mbsf (slightly thinner than 314) while Zone B was 481.6 to 547.1 mbsf (slightly thicker than 314).	LWD was given priority over coring within the basin sediments. Logging data were collected using both measurement while drilling (MWD) and wireline logging (WL) techniques. Five WL log runs and three phases of MWD provide a continuous downhole record [40].
Resistivity	Numerous elevated resistivity values between 218.1-400.4 mbsf correlating with sand horizons. Distinct spikes at 270, 295, 370, and 390 mbsf indicating	

	GH occurrence and saturations > 60% [26, 57].	
P-wave	Zone B in Unit II from 481.6-547.1 mbsf is a sand rich interval with elevated free gas (P-wave velocity drop) that correlates to a strong negative polarity reflection in the seismic data This gas-bearing zone occurs ~80 m below the BSR.	Low P-wave velocity correlate with ash layers [40].
Sonic		Sonic data was evaluated by Doan et al. [57] to estimate the total porosity, amount of free gas, and gas distribution downhole using Brie equations for clay. They proposed that *in situ* biogenic gas produced from the organic-rich sediments of the lower forearc migrates upward along dipping permeable strata and accumulates within coarse grain rich strata towards the seaward edge of the basin.
Pore pressure	Abnormally high which could result in gas expulsion from depth.	Hydrostatic See [104]
GH Saturation Estimated from Logs	Miyakawa et al. [59] used logs and sediment porosity data from core samples collected during Expeditions 314 and 315 to calculate gas hydrate saturations (pore fraction) from the resistivity and P-wave velocity logs. Using eight different equations for a robust quantitative analysis, the resulting hydrate saturation baseline ranged from 0-35% and 0-30% for resistivity and P-wave velocity logs, respectively. A discrepancy between P-wave velocity and resistivity derived GH saturation was attributed to the presence of free gas above the BSR. We can confirm that free gas also appears above the BSR as a low velocity zone in our seismic velocity volume and likely reflects a large flux of gas into the GHSZ. Malinverno and Goldberg's [60] analysis of the downhole logs found NGH occurrence in 166 sand layers between 108 and 401 mbsf and defined this as the gas hydrate occurrence zone (GHOZ) with increasing hydrate content with depth approaching the BSR and a maximum saturation of 70%. Jia et al. [61] applied a first-principle-based effective medium model to predict GH saturation from the sonic data collected at Hole C0002A considering both a porefilling model and a matrix supporting model. Results were	-

	compared to those derived from Archie's equations (85.6% at highest peak). Background resistivity of water saturated sediments was calculated to be 1.17-1.18 ohm.m and resistivity of the pore water was determined to range from 0.21-0.22 ohm.m above the BSR. The pore filling model indicated higher saturations than the matrix-supporting model with a maximum difference of 21.1%.	
Sedimentology		
Sedimentation rate within GHSZ	3.08 cm/Kya [26] Unit IV 5.6 to 7.9 Ma and is separated from Unit III by a 1.8 Ma hiatus between 3.8 and 5.6 Ma	No data for the upper basin sediments
Porosity	Porosity generally decreases with depth from approximately 60% near the top of the hole decreasing to about 30% at 1000 mbsf. At the BSR depth of 400 mbsf, porosity is approximately 50% [26; Figure F86].	-
Lithology	See Appendix Figure 2. Dominant lithology is dark, olive-gray, silty, claystone with minor lithologies including sandstone, sandy siltstone, silty claystone, calcareous claystone, and fine ash. Most samples are dominated by a siliciclastic assemblage of clay, quartz, and feldspar, with variable amounts of pelagic carbonate and a minor, but persistent, component of volcanic glass widely distributed. A thick >3 m sand bed was found just above the BSR at about 386 mbsf [26], corresponding to the highest hydrate saturation estimated from Cl- and resistivity logs. Zones of poor recovery were likely unconsolidated sand units. This is a common problem in ocean drilling and is unfortunate for gas hydrate research because these sand beds may host GHs.	See Appendix Figure 1. Four lithologic units were defined. Unit I (0-467 mbsf) and Unit II (upper forearc basin 467-791 mbsf) are silty mudstone with cyclical sand rich layers 10-50 m in thickness and unconsolidated silty mud with silt and sand interbeds and minor interbeds of volcanic ash. Unit I is noted to be turbidit-rich with sandier units than found at C0002, while Unit II sands are finer than Unit I, but overall coarser than sands recovered at C0002. Unit III is marked by an increase in silt content and fine sand layers Unit III is further broken down into Subunit IIIA and Subunit IIIB. IIIB is characterized by a sharp increase in the abundance of organic woody material [40]. This sedimentary package thickens towards the center of the basin and thins out near C0002 where very little organic matter was found constrained to this unit. Because the organic material is mostly wood, kerogen type III, the hydrocarbon produced upon maturation will be natural gas.
Soupy Structure	From 286.53 to 499.76 mbsf, we identified 66 occurrences of soupy fabric from shipboard sedimentology	-

	notes from Holes C0002K and C0002L. Compositionally, 33 soupy structures (example in Appendix Figure 3) were found in muds-silt, 29 in sands, one occurrence in an ash/mud mixture, one sand/mud mixture, and three occurrences in an unidentified lithology.	