Saffer, D., McNeill, L., Byrne, T., Araki, E., Toczko, S., Eguchi, N., Takahashi, K., and the Expedition 319 Scientists
Proceedings of the Integrated Ocean Drilling Program, Volume 319

Data report: particle size analysis of sediments in the Nankai Trough, IODP Expedition 319 Hole C0009A[1]

Peter B. Flemings,[2] Julia S. Reece,[2, 4] Julie Ditkof,[2] Carmen C. Atkins,[2] and Derek Sawyer[3]

Chapter contents

Abstract

We analyzed the particle size distribution of 46 samples from Integrated Ocean Drilling Program (IODP) Expedition 319 Hole C0009A in the Kumano Basin of the Nankai Trough. Using Shepard's classification, we found that most samples fall into the clayey-silt classification. Clayey-silt is composed of 35%–88% silt-size particles, 11%–38% clay-size particles, and <20% sand-sized particles by weight. However, six samples contain more sand-sized particles and thus fall into either the sandy-silt or silty-sand category according to Shepard's classification. Samples at Site C0009 were analyzed over a depth range of 1529–1591 meters below seafloor using the wet-sieve and hydrometer methods.

Introduction

The Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) is a coordinated, multiexpedition drilling project designed to investigate fault slip behavior and the mechanics of seismogenesis along a subduction megathrust fault system through direct sampling, in situ measurements, and long-term monitoring associated with laboratory and numerical modeling studies (Saffer et al., 2009). As part of the NanTroSEIZE program, operations during Integrated Ocean Drilling Program (IODP) Expedition 319 included riser and riserless drilling, analyses of cuttings and core samples, downhole measurements and logging, observatory operations, and casing. Two sites were drilled during Expedition 319: Site C0009 in the Kumano forearc basin and Site C0010 across a major splay fault (termed the "megasplay") that bounds the seaward edge of the forearc basin near its updip terminus. We analyze the grain size of samples from Site C0009, which is located at the northern edge of the 3-D seismic volume acquired in 2006 (Fig. F1).

Hole C0009A was cored from 1509.7–1593.9 meters below seafloor (mbsf). The strata in this interval are late Miocene in age and are described as brown-gray silty-claystone, with minor interbeds of brown-gray siltstone-sandstone, and minor interbeds of light gray fine vitric tuff. Four lithofacies were defined based on the relative abundance of these lithologies (see the "Site C0009" chapter [Expedition 319 Scientists, 2010]).

To create a depth profile of particle sizes at Site C0009, we analyzed the particle size distribution of 46 samples. The results may

[1]Flemings, P.B., Reece, J.S., Ditkof, J., Atkins, C.C., and Sawyer, D., 2015. Data report: particle size analysis of sediments in the Nankai Trough, IODP Expedition 319 Hole C0009A. *In* Saffer, D., McNeill, L., Byrne, T., Araki, E., Toczko, S., Eguchi, N., Takahashi, K., and the Expedition 319 Scientists, *Proc. IODP,* 319: Tokyo (Integrated Ocean Drilling Program Management International, Inc.).
doi:10.2204/iodp.proc.319.203.2015
[2]Jackson School of Geosciences, University of Texas, Austin TX 78705, USA. Correspondence author: **pflemings@jsg.utexas.edu**
[3]Department of Earth and Environmental Sciences, University of Kentucky, Lexington KY 40506, USA.
[4]Department of Geophysics, Stanford University, Stanford CA 94305, USA.

provide a useful constraint to understand how lithology impacts physical properties (e.g., permeability, compressibility, and porosity) and may assist in interpreting the paleogeographic evolution of the Kumano Basin. Our procedure and results are presented below (Tables T1, T2). A nomenclature table is included (Table T3).

Methods

To create a depth profile of particle sizes at Site C0009, we analyzed the particle size distribution of a total of 46 samples. The samples were primarily from 10 cm^3 plug samples taken shipboard. The wet-sieve and hydrometer techniques were used, which generated particle size distributions for each sample. The procedure used at the University of Texas at Austin (USA) for this study is described below. It is slightly modified from that used in Sawyer et al. (2008). This procedure is internationally recognized as a standard in the American Standard for Testing and Materials (ASTM International, 2007) and in the British Standard Institution (British Standard Institution, 1990). These size distributions were binned into sand, silt, and clay percentages for each sample. We used a clay-silt-sand ternary diagram using the Shepard classification (Shepard, 1954) to classify the samples.

Principles of hydrometer analysis

Germaine and Germaine (2009) discuss hydrometer analysis and the physical principles of sedimentation. The terminal velocity at which spherical particles settle through a column of fluid can be described by Stokes' law (Craig, 1992). Stoke's law assumes that particles are (1) rigid, spherical, and smooth; (2) of similar density; (3) separated from each other; (4) do not interact during sedimentation; and (5) are large enough that Brownian motion does not control settlement. This approach is applicable for particle sizes ranging from 0.0002 to 0.1 mm (Germaine and Germaine, 2009). The general approach is to mix the sediment into a suspension and then allow sedimentation while measuring the density of the suspended sediment at a specific depth.

The diameter of the largest particle in suspension (D) is

$$D = \sqrt{\frac{18\mu}{\rho_w g(G_s - 1)} \times \frac{L}{t}}, \qquad (1)$$

where

D = diameter of the particle (cm),
μ = viscosity of water (g/[cm·s]),
G_s = specific gravity of sediment (dimensionless),
ρ_w = water density (g/cm^3),
g = force of gravity (cm/s^2),
L = distance the particle falls (cm), and
t = time for fall (s).

The percent finer material (N) at reading m is

$$N_m = \frac{G_s}{G_s - 1}\left(\frac{V}{M_D}\right)\rho_c(R_m - R_{w,m} \times 100), \qquad (2)$$

where

N_m = percent finer material at reading m (%),
G_s = the specific gravity of sediment (dimensionless),
V = volume of suspension (mm^3),
M_D = dry solid mass of hydrometer specimen (g),
R_m = hydrometer reading in suspension at time (t) and temperature, T (dimensionless),
$R_{w,m}$ = hydrometer reading in water with dispersant at the same temperature as for R_m (dimensionless), and
m = reading number.

Samples

We analyzed 46 samples distributed across the interval between 1529 and 1591 mbsf. We analyzed samples with a wet mass between 25 and 45 g because it was determined that a mass <25 g produced inaccurate results.

Sample preparation

Samples were first manually disaggregated using a mortar and pestle. After recording the wet mass, the wet sample was mixed with 5 g of dispersing agent (sodium hexametaphosphate) and ~200 mL of deionized water and allowed to sit for 24–48 h. The mixture was further disaggregated for 1 min using a Hamilton-Beach malt mixer (ASTM International, 2007).

Once the sample was mixed, the slurry was washed through a 63 µm sieve with deionized water and a spatula. Material that was unable to pass through the sieve was dried at 110°C. The sample was then cooled and weighed to determine the percentage of sand for each sample.

The material that passed through the sieve was placed in a 1000 mL plastic cylinder and deionized water was added to create a total volume of 1000 mL. Five to six cylinders were usually tested at one time.

Hydrometer analysis

The prepared suspension was mixed thoroughly with a plunging rod for 1 min. The removal of the plunging rod marked the beginning of the sedimentation process. Two sets of hydrometer readings were obtained for the first 2 min (each at 15, 30, 60, 90, and 120 s) of sedimentation with the hydrometer remaining in the suspension. The hydrometer was then removed, rinsed and wiped dry. Readings were then taken at larger increments of time (4, 8, 16, 32, 64, etc., minutes), with the hydrometer being inserted and removed right before and after the time mark, until the largest particle in solution (Equation 1) was >0.002 m (the clay/silt boundary assumed). The temperature in the laboratory was monitored with a thermometer in a cylinder filled with deionized water and salt. At the end of the experiment, the slurry was poured into an evaporating dish and dried in an oven at 110°C to obtain the final dry mass of sediment and dispersing agent.

The hydrometer has to be calibrated prior to testing to obtain information for three factors: the meniscus rise, the effective reading depth for any particular reading, and the changes in fluid density with temperature and dispersing agent (Germaine and Germaine, 2009). For the effective reading depth (L), two relationships are required: one for situations when the hydrometer remains in the suspension continuously and one for situations when the hydrometer is inserted for the reading (Germaine and Germaine, 2009). For times ≤2 min, the effective reading depth (L) is described by

$$L = H_{r,1} - \frac{(H_{r,1} - H_{r,2})}{(R_{h,2} - R_{h,1})} \times (R_h + c_{mr} - R_{h,1}), \quad (3)$$

where

- L = effective reading depth for situations when the hydrometer remains in the suspension continuously (cm),
- $H_{r,1}$ and $H_{r,2}$ = dimension between the center of buoyancy and readings $R_{h,1}$ and $R_{h,2}$ on the hydrometer (cm),
- R_h = hydrometer reading in suspension (g/L) at time (t) and temperature (T), and
- c_{mr} = meniscus correction in units of specific gravity (dimensionless).

For times <2 min, an immersion correction ($V_h/2A$) was applied to the readings to account for the fact that the insertion of the hydrometer into the suspension stretches the column of fluid:

$$L = H_{r,1} - \frac{(H_{r,1} - H_{r,2})}{(R_{h,2} - R_{h,1})} \times (R_h + c_{mr} - R_{h,1}) - \frac{V_h}{2A}, \quad (4)$$

where

- L = effective reading depth for situations when the hydrometer is inserted before individual readings (cm)
- V_h = volume of hydrometer bulb up to the base of the stem (cm^3), and
- A = cross-section area of cylinder (cm^2).

Grain densities were not measured on the samples that we performed grain size analysis on. Instead, density was estimated from shipboard moisture and density (MAD) measurements. These measurements ranged between 2.42 and 3.01 g/cm^3 (Table T2). We used the average of two or three MAD grain density measurements take near the depths of the sample that we performed grain size analysis on.

Results

Particle size distribution curves were created for all 46 samples. Table T1 gives the sand, silt, and clay percentages calculated using the hydrometer analysis. Figures F2 and F3 show an example data sheet and plot for our hydrometer analysis (see GRAINSIZ in "Supplementary material" for similar graphs for each sample).

Figure F4 shows a particle distribution graph showing depth versus grain density and weight percent clay. Because we did not measure the density of the actual grain size samples, we determined an error resulting from using MAD density values from depths that are close to the depth of the grain size samples. To test the error in our grain density, we present the data using three constant grain density values. We calculated all grain size distributions to have a grain density of 2.7 g/cm^3 as an average specific gravity. We then altered all 46 samples to have a specific gravity of 2.6 and 2.8. The fraction of clay present varied only ±0.8% compared to the grain size distribution with a specific gravity of 2.7. This demonstrates that variation in grain density over a reasonable range has a small effect on the interpreted grain size distribution.

Using the ternary diagram in Figure F5, we plot the sand, silt, and clay percentages for all 46 samples. Nearly all samples are within the clayey-silt field with a few scattered sandy-silts, silty-sands, and sands. The samples are more clay rich in the uppermost section, as seen in the particle distribution graph (Fig. F6).

The downcore profile for sand, silt, and clay against gamma ray, spontaneous potential, resistivity, lithology, and core information is shown in Figure F6.

Reproducibility

We used excess material from the samples to run a repeat experiment of Sample 319-C0009A-5R-1W, 126.0–129.5 cm. We conducted one test where multiple hydrometer runs were taken on a single sample. The initial masses of the samples were varied (37.52 and 31.61 g) (Fig. F7).

The particle size distribution curves generally match each other with only minor variation in two parts (Fig. F7). This deviation can be explained by recognizing the material was not homogenized. They were taken from the same core, interval, and depth, but were separated into two packages. We assume therefore that our methods are reproducible.

Acknowledgments

All samples used in this study were collected during Integrated Ocean Drilling Program (IODP) Expedition 319. Funding for this research was provided by the U.S. Science Support Program, administered by the Consortium for Ocean Leadership. We thank the Expedition 319 crew and science party.

References

ASTM International, 2007. Standard test method for particle-size analysis of soils (Standard D422-63[2007]). In *Annual Book of ASTM Standards* (Vol. 04.08): *Soil and Rock* (I): West Conshohocken, PA (Am. So. Testing Mater.). **doi:10.1520/D0422-63R07**

British Standards Institution, 1990. *Methods of Test for Soils for Civil Engineering Purposes* (Standard BS-1377[1990]): London (British Standards Inst.).

Craig, R.F., 1992. *Soil Mechanics* (5th ed.): London (Chapman and Hall).

Expedition 319 Scientists, 2010. Site C0009. *In* Saffer, D., McNeill, L., Byrne, T., Araki, E., Toczko, S., Eguchi, N., Takahashi, K., and the Expedition 319 Scientists, *Proc. IODP,* 319: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.319.103.2010**

Germaine, J.T., and Germaine, A.V., 2009. *Geotechnical Laboratory Measurements for Engineers:* Hoboken, NJ (Wiley). **doi:10.1002/9780470548790**

Heki, K., 2007. Secular, transient, and seasonal crustal movements in Japan from a dense GPS array: implication for plate dynamics in convergent boundaries. *In* Dixon, T.H., and Moore, J.C. (Eds.), *The Seismogenic Zone of Subduction Thrust Faults:* New York (Columbia Univ. Press), 512–539.

Saffer, D., McNeill, L., Araki, E., Byrne, T., Eguchi, N., Toczko, S., Takahashi, K., and the Expedition 319 Scientists, 2009. NanTroSEIZE Stage 2: NanTroSEIZE riser/riserless observatory. *IODP Prel. Rept.,* 319. **doi:10.2204/iodp.pr.319.2009**

Sawyer, D.E., Jacoby, R., Flemings, P., and Germaine, J.T., 2008. Data report: particle size analysis of sediments in the Ursa Basin, IODP Expedition 308 Sites U1324 and U1322, northern Gulf of Mexico. *In* Flemings, P.B., Behrmann, J.H., John, C.M., and the Expedition 308 Scientists, *Proc. IODP,* 308: College Station, TX (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.308.205.2008**

Seno, T., Stein, S., and Gripp, A.E., 1993. A model for the motion of the Philippine Sea plate consistent with NUVEL-1 and geological data. *J. Geophys. Res.: Solid Earth,* 98(B10):17941–17948. **doi:10.1029/93JB00782**

Shepard, F.P., 1954. Nomenclature based on sand-silt-clay ratios. *J. Sediment. Res.,* 24(3):151–158. **doi:10.1306/D4269774-2B26-11D7-8648000102C1865D**

Initial receipt: 19 April 2013
Acceptance: 21 January 2015
Publication: 1 May 2015
MS 319-203

Figure F1. Map of study area showing drill sites, Sites C0009 and C0010 (green diamonds) (modified from Saffer et al., 2009). Red circles = NanTroSEIZE Stage 1 sites, black box = location of 3-D reflection data acquisition in 2006, yellow arrows = vectors estimated far-field between Philippine Sea plate and Japan (Heki, 2007; Seno, 1993), stars = large earthquakes in the past.

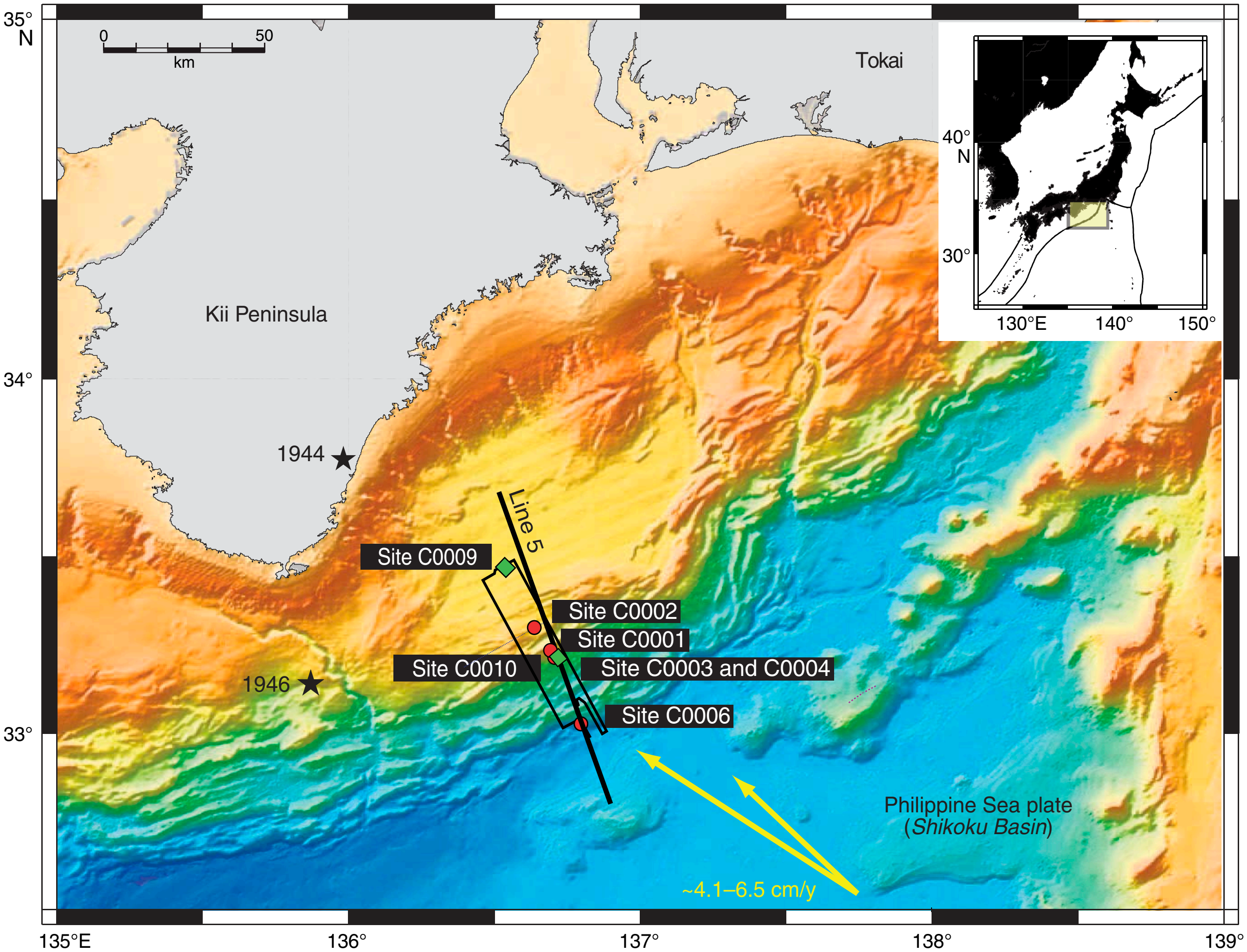

Figure F2. Example data sheet for hydrometer analyses, Site C0009.

Hydrometer Analysis

Test No: GS054
Project : IODP Expedition 319
Tested by: CAA
Test Date: 4/20/2010

Boring : C0009A
Sample : 3R-1 54-62 cm
Location : Nankai
Spec. Grav. = 2.66
Dry Soil Mass = 36.18 (gm)
Mass Disp. = 5.00 (gm)

Hydrometer: 151H Fisher Brand
Number = 98
Volume = 69.59 (cm^3)
Hr @ 1035 = 8.2 (cm)
Hr @ 1000 = 17.5 (cm)
Meniscus = 0.4 (gm/l)

Volumetric
Volume = 1000 (cm^3)
Area = 28.77 (cm^2)

Mass Measurement
Tare, soil, disp. = 353.35 (gm)
Tare = 316.25 (gm)

Note: Disp. not included in dry mass.
Note: Read hydrometer to 0.2 gm/l

Measurements					Constants		Results	
Date (mm/dd/yyyy)	Elasped Time (min)	Suspension Reading (SG*1000)	Water / Disp. Reading (SG*1000)	Temp. (C)	Viscosity (gm-sec/cm^2)	Reading Depth (cm)	Percent Finer (%)	Diameter (mm)
4/20/2010	0.33	1023.1	1003.9	23.0	9.56E-06	11.3	85.2	0.07678
4/20/2010	0.5	1022.7	1003.9	23.0	9.56E-06	11.4	83.4	0.06267
4/20/2010	1	1021.9	1003.9	23.0	9.56E-06	11.6	79.9	0.04473
4/20/2010	1.5	1021.1	1003.9	23.0	9.56E-06	11.8	76.3	0.03685
4/20/2010	2	1020.5	1003.9	23.0	9.56E-06	11.9	73.7	0.03213
4/20/2010	4	1019.2	1003.9	23.0	9.56E-06	11.1	67.9	0.02188
4/20/2010	8.0	1018.1	1003.9	23.0	9.56E-06	11.4	63.0	0.01568
4/20/2010	16	1016.2	1003.9	23.0	9.56E-06	11.9	54.6	0.01133
4/20/2010	32	1014.9	1003.9	23.0	9.56E-06	12.2	48.9	0.00813
4/20/2010	65	1013.2	1003.9	23.0	9.56E-06	12.7	41.3	0.00581
4/20/2010	128	1012.0	1003.9	23.0	9.56E-06	13.0	36.0	0.00419
4/20/2010	210	1011.0	1003.9	23.0	9.56E-06	13.3	31.6	0.00330
4/20/2010	460	1010.0	1003.9	23.0	9.56E-06	13.5	27.1	0.00225
4/20/2010	1413	1009.6	1003.9	23.0	9.56E-06	13.6	25.4	0.00129
4/21/2010	1891	1009.2	1003.9	23.0	9.56E-06	13.7	23.6	0.00112
4/21/2010	2843	1007.8	1003.9	23.0	9.56E-06	14.1	17.4	0.00093
4/26/2010	10042	1006.9	1003.9	23.0	9.56E-06	14.4	13.4	0.00050

Sieve Data (wet sieved at 63 µm)
Mass retained on sieve: 4.080 (gm)
Sand-percent of dry mass: 11.28 (%)
Percent passing 63 µm: 88.72 (%)
Diameter: 0.0630 (mm)

Interpolated silt/clay boundary (at 2 µm)
Percent passing 2 µm: 26.7 (%)
Diameter: 0.002 (mm)

Remarks: For times greater than 2 minutes, an immersion correction is applied to the readings.

Figure F3. Sample particle size distribution plotted on a semilog scale, Site C0009. Black circles = hydrometer readings, diamond = sand fraction from wet sieving through 63 µm sieve. The sand/silt boundary is defined at 63 µm and the silt/clay boundary is defined at 2 µm. See GRAINSIZ in **"Supplementary material"** for test results.

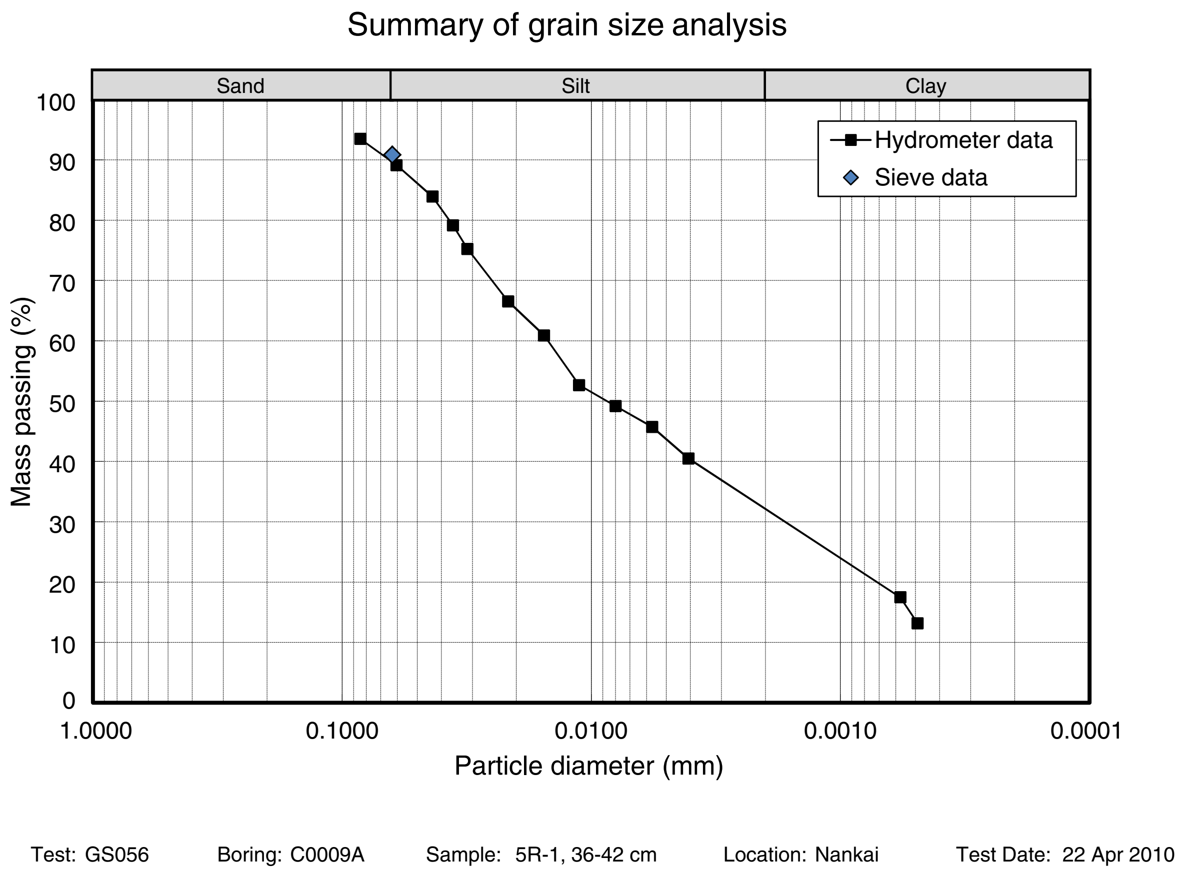

Figure F4. Grain density and clay fraction vs. depth for all measured samples, Site C0009. **A.** Grain density measured by shipboard scientists (Table T2). **B.** Grain density used for analyses, determined by averaging two or three MAD grain density measurements. **C.** Clay fractions determined from hydrometer analyses using grain density shown in B. Gray = clay fraction, white = silt and sand fraction. Positive and negative error bars in clay fraction are determined from using grain density values of 2.6 and 2.8 g/cm³ relative to 2.7 g/cm³ in the clay fraction calculation, respectively.

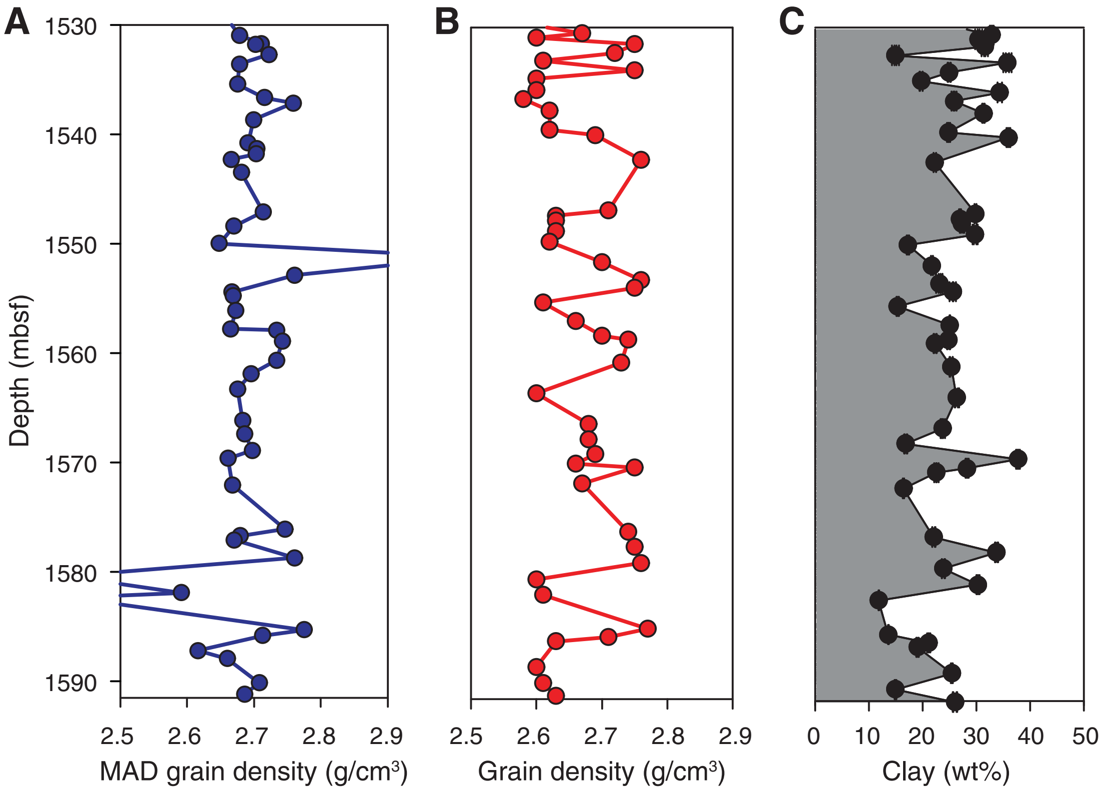

Figure F5. Ternary diagram of all 46 samples from Hole C0009A using Shepard's (1954) sediment classification scheme.

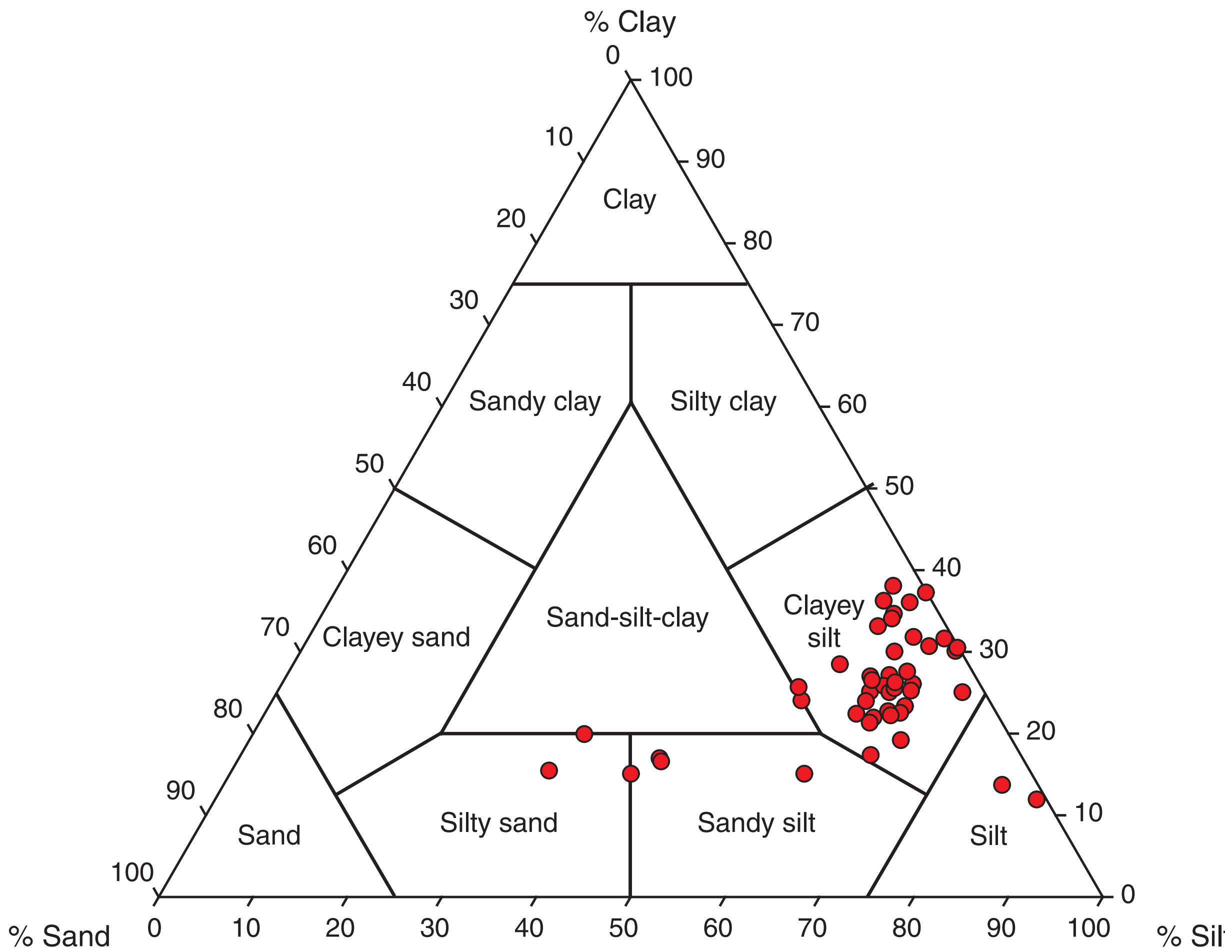

Figure F6. Summary plot of downhole logs and particle distribution, Site C0009. Spontaneous potential (SP), gamma ray (GR), and resistivity are wireline data. Lithologic fractions were experimentally determined by our grain size analyses of all 46 samples. Core recovered: black = actual interval of sediment retrieved by the expedition, white = gaps where no core was recovered. Each core was assigned a core number. Lithologic units were defined by shipboard sedimentologists.

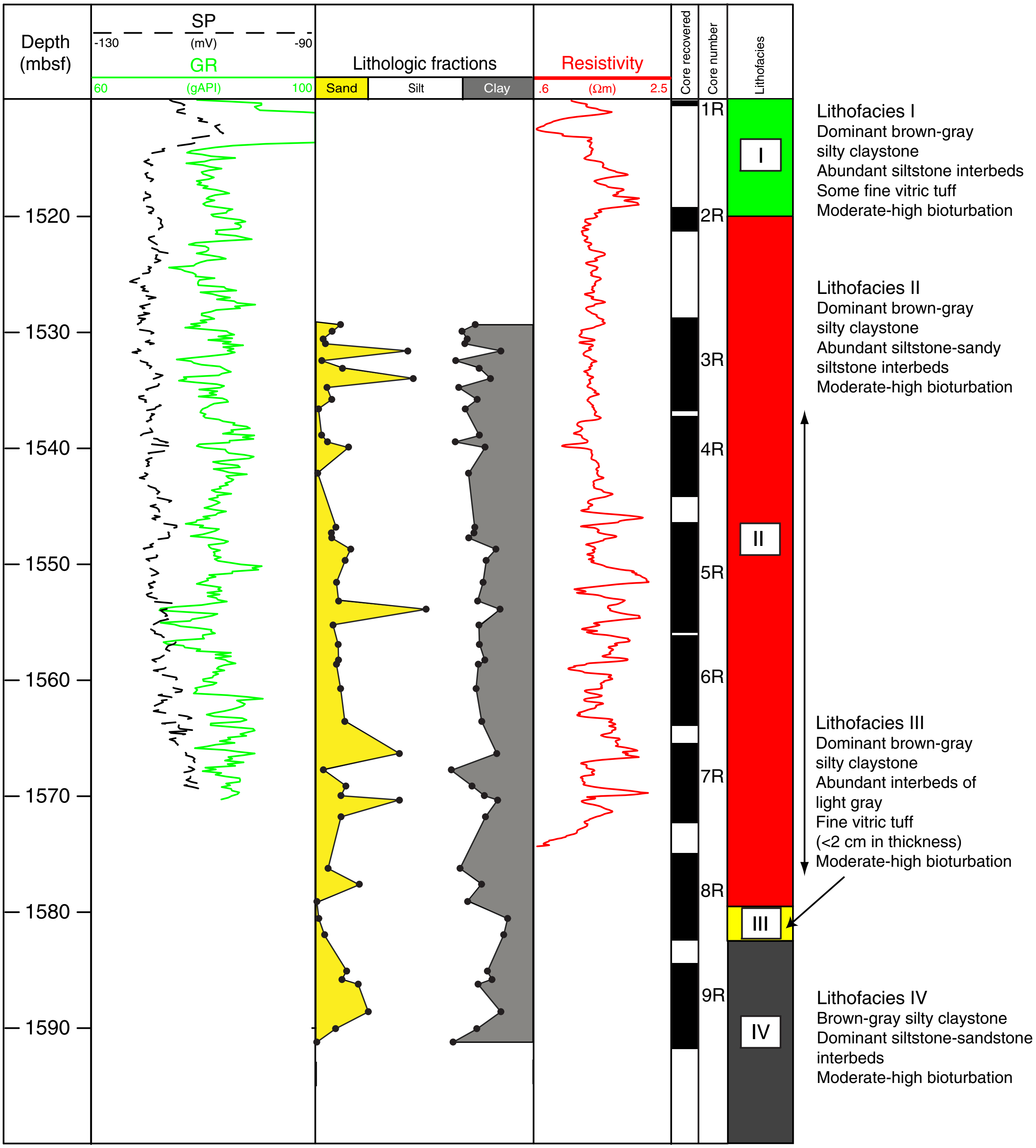

Figure F7. Graph of two hydrometer tests (GS071 and GS115) on the same sample from 1547.66 mbsf to illustrate reproducibility. The initial mass of the samples also varied. Sample GS115 had a mass of 31.61 g and Sample GS071 had a mass of 37.52 g.

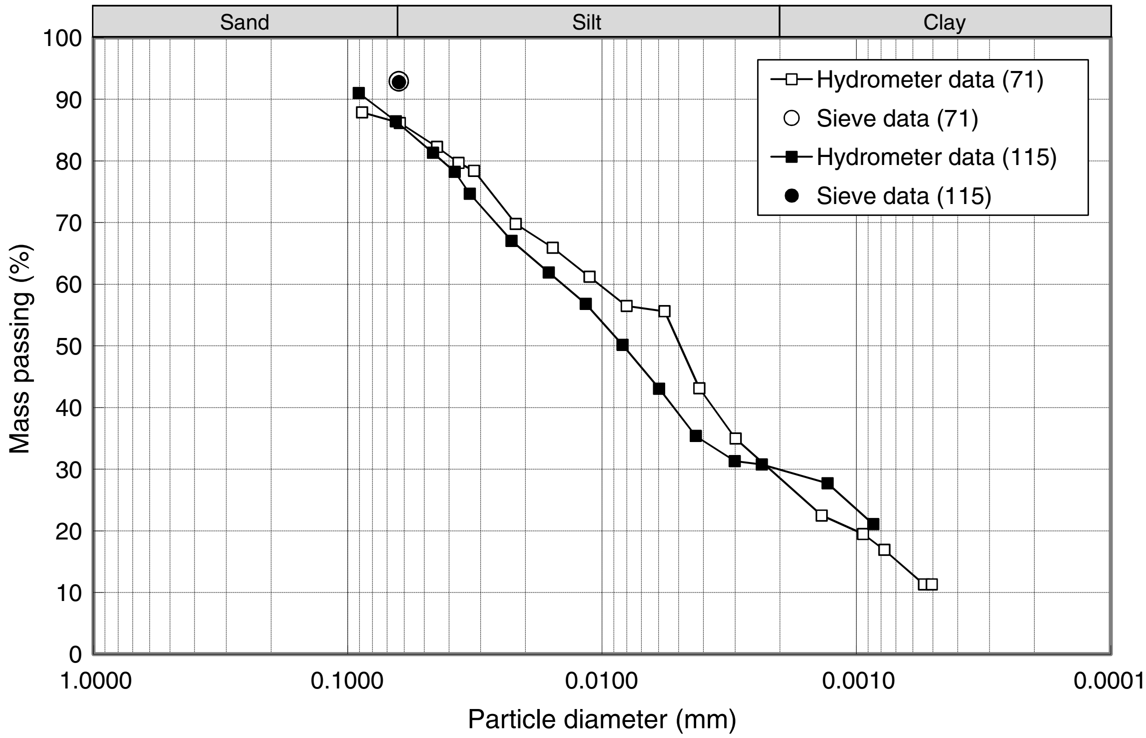

Table T1. Hole C0009A core summary and particle size distribution data.

Core information		Grain size information			
Core, section, interval (cm)	Depth (mbsf)	Test number	Sand (wt%)	Silt (wt%)	Clay (wt%)
319-C0009A-					
3R-1, 58.0–62.0	1529.28–1529.32	GS054	11.3	62.0	26.7
3R-1, 114.5–116.0	1529.845–1529.86	GS111	7.4	59.8	32.8
3R-2, 40.5–44.5	1530.515–1530.555	GS069	3.3	66.4	30.4
3R-2, 81.0–85.0	1530.92– 1530.96	GS112	4.4	64.2	31.5
3R-3, 17.5–21.5	1531.545–1531.585	GS106	42.3	42.8	14.9
3R-4, 32.0–36.0	1532.365–1532.405	GS076	2.7	61.6	35.7
3R-4, 99.0–103.0	1533.035–1533.075	GS120	12.2	62.9	24.9
3R-5, 44.0–48.0	1533.92 –1533.96	GS107	44.8	35.5	19.7
3R-5, 122.0–127.0	1534.7–1534.75	GS114	5.0	60.7	34.3
3R-6, 84.0–88.5	1535.735–1536.115	GS081	7.2	67.0	25.8
3R-7, 24.0–28.0	1536.545–1536.585	GS087	1.2	67.5	31.3
4R-2, 51.0–56.0	1538.81–1538.86	GS070	2.6	72.6	24.8
4R-2, 107.0–111.0	1539.37–1539.41	GS116	5.3	58.8	35.9
4R-4, 11.0–15.0	1539.86–1539.9	GS077	15.0	62.8	22.2
4R-7, 25.0–29.0	1542.11–1542.15	GS088	0.8	69.4	29.8
5R-1, 36.0–42.0	1546.76–1546.82	GS056	9.2	64.0	26.9
5R-1, 85.5–90.5	1547.255–1547.305	GS071	7.1	65.6	27.3
5R-1, 126.0–129.5	1547.66–1547.695	GS115	7.2	63.1	29.7
5R-2, 85.5–90.5	1548.655–1548.705	GS118	16.0	66.8	17.2
5R-3, 48.0–52.5	1549.62 –1549.665	GS074	13.4	64.9	21.7
5R-5, 53.5–58.0	1551.495– 1551.54	GS082	9.4	67.5	23.1
5R-6, 127.0–131.0	1553.12–1553.16	GS086	10.4	64.0	25.6
5R-7, 61.0–65.0	1553.85–1553.89	GS105	50.7	34.0	15.3
5R-8, 55.0–59.0	1555.2–1555.24	GS122	7.9	67.2	25.0
6R-1, 100.0–104.0	1556.9–1556.94	GS057	10.2	65.0	24.8
6R-3, 39.0–41.5	1558.235–1558.26	GS119	10.3	67.4	22.3
6R-4, 28.0–32.0	1558.575–1558.615	GS078	9.4	65.3	25.3
6R-5, 98.0–102.0	1560.69–1560.73	GS083	11.3	62.4	26.3
6R-7, 97.0–101.0	1563.51–1563.55	GS110	13.3	63.1	23.7
7R-1, 90.0–94.0	1566.3–1566.66	GS058	38.4	44.8	16.8
7R-2, 90.0–94.0	1567.705–1567.745	GS072	3.4	58.9	37.7
7R-3, 88.0–92.0	1569.095–1569.135	GS075	13.7	58.1	28.2
7R-4, 30.5–34.5	1569.93–1569.97	GS079	11.5	66.0	22.5
7R-4, 69.0–73.0	1570.315–1570.355	GS104	38.4	45.2	16.4
7R-5, 72.0–76.0	1571.76–1571.8	GS084	11.5	66.5	22.0
8R-1, 128.0–133.0	1576.18–1576.23	GS059	5.5	60.8	33.7
8R-4, 69.0–72.0	1577.58–1577.61	GS108	20.0	56.3	23.8
8R-5, 74.0–78.0	1579.05–1579.09	GS085	0.4	69.4	30.2
8R-6, 80.0–84.0	1580.53–1580.57	GS117	1.3	86.9	11.8
8R-7, 78.0–82.0	1581.95–1581.99	GS123	4.0	82.4	13.6
9R-1, 67.0–71.0	1585.07–1585.11	GS060	14.1	64.8	21.1
9R-2, 0.0–4.0	1585.8–1585.84	GS073	11.9	69.1	19.0
9R-2, 41.0–45.0	1586.21–1586.25	GS109	19.4	55.2	25.4
9R-4, 77.0–81.0	1588.58–1588.62	GS080	24.1	61.0	14.9
9R-6, 81.0–85.0	1590.05–1590.09	GS121	9.0	65.0	26.0
9R-7, 55.0–58.0	1591.2–1591.23	GS113	0.3	62.8	36.9

Table T2. Hole C0009A grain density measurements from moisture and density (MAD) measurements.

Top core depth below seafloor (m CSF-A)	MAD Method C grain density (g/cm^3)
1509.8	2.4447
1519.57	2.6737
1520.18	2.6776
1529.48	2.6615
1530.96	2.6781
1531.71	2.7111
1531.77	2.7024
1532.685	2.7224
1533.58	2.6785
1535.415	2.676
1536.635	2.7154
1537.155	2.759
1538.65	2.6993
1540.78	2.6913
1541.33	2.7039
1541.79	2.7035
1542.28	2.666
1543.5	2.6811
1547.08	2.7137
1548.39	2.67
1549.99	2.6485
1551.22	3.0145
1552.87	2.7612
1554.41	2.6671
1554.78	2.6689
1556.1	2.6726
1557.79	2.6657
1557.895	2.7344
1558.91	2.7428
1560.64	2.7342
1561.925	2.6961
1563.27	2.6755
1566.16	2.6834
1567.385	2.6866
1568.875	2.6975
1569.625	2.661
1572.06	2.6678
1576.075	2.7463
1576.7	2.6794
1577.08	2.6705
1578.7	2.7608
1580.35	2.4217
1581.92	2.592
1582.3	2.4206
1585.28	2.7749
1585.8	2.7128
1587.2	2.6162
1587.93	2.66
1590.15	2.7081
1591.16	2.6862

Table T3. Nomenclature.

Name	Definition	Unit
D	Particle diameter	cm
g	Gravitational force	cm/s^2
G_s	Specific gravity of sediment	dimensionless
L	Distance the particle falls	cm
m	Reading number	dimensionless
M_D	Dry solid mass of hydrometer specimen	g
N_m	Percent-finer material at reading m	%
V	Volume of suspension	mm^3
R_m	Hydrometer reading in suspension at time (*t*), and temperature, (*T*)	dimensionless
$R_{w,m}$	Hydrometer reading in water with dispersant at the same temperature as for R_m	dimensionless
t	Time for particle to fall	s
μ	Viscosity of water	g/(cm·s)
ρ_w	Water density	g/cm^3