Suyehiro, K., Sacks, I.S., Acton, G.D., and Oda, M. (Eds.)
Proceedings of the Ocean Drilling Program, Scientific Results Volume 186

10. Late Quaternary Tephrostratigraphy of the Sediments from the Japan Trench Forearc, Holes 1150A and 1151C[1]

Kaori Aoki[2] and Tatsuhiko Sakamoto[3]

ABSTRACT

The sediments collected at Sites 1150 and 1151 during Leg 186 included many tephra layers and volcaniclastic detritus. In order to identify these tephras, the major oxide compositions of individual glass shards were determined by electron probe microanalyzer.

The uppermost four tephras in sediments from Hole 1150A are correlated with the Towada-Hachinohe tephra (To-H; Tohoku district), Shikotsu Daiichi (1st) tephra (Spfa-1; Hokkaido district), Narugo-Yanagisawa tephra (Nr-Y; Tohoku district), and Aso-4 tephra (Kyushu district), respectively. The uppermost tephra in Hole 1151C is correlated with To-H tephra.

To-H, Spfa-1, and Aso-4 tephras are also present in piston core KH94-3, LM-8, collected between Sites 1150 and 1151. Eruptive ages of To-H and Spfa-1 estimated from the oxygen isotopic Stages of core KH94-3, LM-8 are between 14.9–15.3 and 39.5–40.1 ka.

INTRODUCTION

Japan and the surrounding islands have many island-arc volcanoes. The Pacific side of the volcanic belts is sharply delineated by the volcanic front, characterized by a dense population of volcanic vents (Aramaki and Ui, 1982). Tephra study plays an important role in establishing a chronostratigraphic framework for physical volcanology over

[1]Aoki, K., and Sakamoto, T., 2003. Late Quaternary tephrostratigraphy of the sediments from the Japan Trench forearc, Holes 1150A and 1151C. *In* Suyehiro, K., Sacks, I.S., Acton, G.D., and Oda, M. (Eds.), *Proc. ODP, Sci. Results,* 186, 1–22 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/186_SR/VOLUME/CHAPTERS/116.PDF>. [Cited YYYY-MM-DD]
[2]Geological Survey of Japan, AIST, Tsukuba Central 7, 1-1, Higashi 1-Chome, Tsukuba-shi, Ibaraki-ken 305-8567, Japan. **aoki-kao@aist.go.jp**
[3]Program for Paleoenvironment Institute for Frontier Research on Earth Evolution (IFREE), Japan Marine Science and Technology Center (JAMSTEC), 2-15 Natsushima-cho, Yokosuka 237-0061, Japan.

Initial receipt: 4 January 2002
Acceptance: 10 October 2002
Web publication: 19 March 2003
Ms 186SR-116

extensive areas. Since the 1930s, tephrochronologic methods have been used extensively to solve problems in Quaternary geology, archaeology, paleopetrology, and paleogeography. In these fields, the presence of tephra layers has been noted in many studies and several catalogs have been compiled (Arai et al., 1986; Machida and Arai, 1992).

The North Pacific Ocean is the largest and deepest sedimentary basin in the world, and the island arcs facing the ocean are volcanically active. Nevertheless, tephra studies of samples recovered from this area have not been numerous. During the 1960's, the Lamont Geological Observatory recovered more than 300 piston cores from the North Pacific (Horn et al., 1969). Thin layers of volcanic ash in cores have been taken from a zone 600 to 800 mi (990 to 1290 km) wide around the western and northern limits of the North Pacific Basin, and no volcanic ash layers were found in cores taken north of the volcanic Hawaiian Ridge. In the East Pacific Ocean, Mazama ash in the piston core recovered off the coast of Washington and Oregon was correlated (Nelson et al., 1968; Smith and Westgate, 1969). Subsequent to these efforts, few studies have been conducted on tephras from the North Pacific Ocean. Furuta et al. (1986) identified six widespread tephras off the Kashima Coast and Shikoku Basin, but the northernmost core site is only at 35°N latitude in the northwest Pacific.

Aoki and Arai (2000) studied piston core KH94-3, LM-8 (38°N) collected from the continental slope between Sites 1150 and 1151, off Sanriku, the east coast of North Honshu, Japan. This core contains 14 tephra layers, and the lowermost one is assigned to Aso-4 (Machida et al., 1985) by Shimizu et al. (1997). Characterization of these tephras is based on major element compositions of the volcanic glass and refractive indexes of glass shards and minerals, indicating that there are widespread tephras from such distal volcanoes as in Kyushu, central Honshu, and Hokkaido, in addition to several nearby volcanoes in Tohoku. It is suggested that the pelagic sediments off northeast Japan are one of the most important sources of samples in order to construct a standard tephrostratigraphy in Japan.

The chemical compositions and mineral assemblages of marine tephras were examined to determine if the marine tephras can be correlated with on-land marker tephras at type localities. On the basis of such identified tephra layers, the standard tephrostratigraphy of Japan since the late Tertiary and the distribution of tephras in the northwest Pacific may be refined and revised.

In this report, all tephra layers and detritus observed in sediments at Sites 1150 and 1151 are listed in Tables **T1, T2, T3,** and **T4.** Furthermore, the correlations between some tephra in the uppermost sediments of Sites 1150 and 1151 and their correlatives in core KH94-3, LM-8 are reported.

T1. Tephra layers, Hole 1150A, p. 8.

T2. Tephra layers, Hole 1151A, p. 11.

T3. Tephra layers, Hole 1151C, p. 12.

T4. Tephra layers, Hole 1151D, p. 15.

MATERIALS

The sediments collected at Sites 1150 and 1151 during Leg 186 were obtained in the forearc terrace of the Japan Trench (Sacks, Suyehiro, Acton, et al., 2000) and contain many tephra layers and detritus. Hole 1150A contains 88 tephras (Table **T1**), Hole 1151A contains 430 tephras (Table **T2**), Hole 1151C contains 97 tephras (Table **T3**), and Hole 1151D includes 142 tephras (Table **T4**).

Tephra materials in this area are generally coarse grained and normally graded, indicative perhaps of relatively proximal sources. There

are some tephras consisting of fine- and vitric-grained materials. It is suggested that source volcanoes in these instances may be distant. Many tephras are disturbed by benthos, turbidity currents, or other phenomena.

METHODS

The major element composition of volcanic glass shards in the uppermost 6 tephras of Hole 1150A and uppermost 20 tephras of Hole 1151C were determined by electron probe microanalyzer (EPMA). The mineral assemblage and morphological characteristics of volcanic glass shards were observed with a binocular microscope.

Glass shards concentrated from the 63- to 250-µm size fraction were mounted in epoxy resin, ground, polished, and carbon coated. Samples were analyzed with an automated wavelength dispersive JEOL-8900R microprobe analyzer (Geological Survey of Japan, AIST) operated at 15 kV and using a 10-nA beam current and a 10-µm beam diameter to minimize loss of Na and K (Froggatt, 1983). Na and K were always analyzed first. Counting times of 10 s (2 × 5 s, at peak) were used.

TEPHRA CORRELATIONS

The major element compositions, averages, and standard deviations are presented in Table **T5.** The major element compositions of volcanic glass shards of representative marker tephras from Aoki and Arai (2000) are listed in Table **T6.**

Tephra correlation is determined on the basis of the similarity coefficient (SC) (Table **T7**). The SC is calculated between the composition averages of the marine and marker tephras. The SC is an average of ratios of elemental concentrations in any two compositional analyses and is given by Borchardt et al. (1972) and Sarna-Wojcicki (1976) as

$$d(A.B) = 1/n\ \Sigma R_i,$$

where

- $d(A.B) = d(B.A)$ = the SC for comparison of sample A and sample B,
- i = element number,
- n = number of elements,
- R_i = X_iA/X_iB if $X_i > X_iA$; otherwise X_iB/X_iA,
- X_iA = concentration of element i in sample A, and
- X_iB = concentration of element i in sample B.

Sample A can be correlated with sample B when the SC is near 1.00. In the general case where the SC is >0.92, such pairs are regarded as equivalent (Froggatt, 1992).

In Hole 1150A, the uppermost six tephra samples (Table **T1**) were analyzed. The SC between these and some representative marker tephras in northeast Japan are presented in Table **T7,** and their correlatives are recognized. Samples 186-1150A-1H-4, 54–56 cm (5.04–5.06 meters below seafloor [mbsf]), and 3H-5, 71–73 cm (23.91–23.93 mbsf), were sourced from the volcanoes in the Tohoku district adjacent to this site. Sample 186-1150A-1H-4, 54–56 cm, is one of some byproducts of the caldera-forming events of the Towada Caldera and are identified as To-

T5. Glass shard composition of tephra, Holes 1150A and 1151C, p. 19.

T6. Glass shard composition of tephra, p. 20.

T7. SC between marine tephras and correlatives, p. 21.

H tephra (15 ka) on the basis of the presence of hornblende (Table T8). Sample 186-1150A-2H-5, 136–138 cm (7.36–7.38 mbsf), is identified as Shikotsu Daiichi (1st) tephra (Spfa-1) (40 ka) from Hokkaido. Samples 186-1150A-1H-CC, 22–26 cm, and 2H-1, 10–12 cm (26.8–26.82 mbsf), are identified as tephra Aso-4 (86–90 ka) from Kyushu district. Sample 186-1150A-3H-3, 148–150 cm (21.68–21.70 mbsf), was possibly derived from the Narugo Caldera and identified as Narugo Yanagisawa (Nr-Y).

In Hole 1151C, the uppermost 20 tephra samples were analyzed. Sample 186-1151C-1H-1, 110–112 cm (1.1–1.12 mbsf), was sourced from the Towada Caldera and correlated with To-H tephra on the basis of the presence of hornblende (Table T8). Sections 186-1151C-2H-1 through 2H-4 (3.58–6.56 mbsf) are highly disturbed, and the individual glass compositions are diverse.

None of the tephra layers in the depth range 10.28–30.56 mbsf can be correlated with any of the known widespread tephra (almost all from Kyushu).

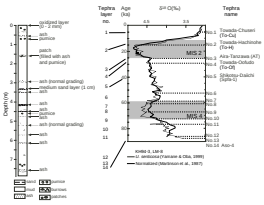
The mineral assemblages and the morphologies of volcanic glass shards are compiled in Table T8.

Tephras To-H and Spfa-1 are also identified in piston core KH94-3, LM-8, collected between Sites 1150 and 1151 (Aoki and Arai, 2000). Oxygen isotope stratigraphy (OIS) of the benthic foraminifer *Uvigerina senticosa* (Yamane and Oba, 1999) has been determined for piston core KH94-3, LM-8. The oxygen isotopic curve (Fig. F1) is similar to the standard curve shown in Martinson et al. (1987). Aoki and Arai (2000) made a comparison of the OIS age with calendar years calibrated from accelerator mass spectrometry (AMS) radiocarbon ages (abbreviated as cal.yrs. BP or cal.ka) of charcoal or wood buried in ignimbrites of tephras To-H and Spfa-1. Recalculations are made on the basis of Stuiver and Reimer (1993), Bard et al. (1992, 1993), and Kitagawa and van der Plicht (1998).

To-H dated as 14.9–15.3 OIS ka seems to be within the time range of 14.1–16.8 cal.yrs.BP. The latter age is converted from nine radiocarbon ages of charcoal in the ignimbrite of To-H. A lot of radiocarbon ages have been reported for the Spfa-1, ranging from 23 to 34 ka. The AMS radiocarbon ages recently obtained are 42 ± 1.8 ka (Yanagida, 1994) and 35.45 ± 1.1 and 34.75 ± 0.5 ka (Kato et al., 1995). Calibration of 42 ± 1.8 ka (Yanagida, 1994) with the calendar age is not easy, but 45 cal.ka for this tephra is possible on the basis of the figure presented by Kitagawa and van der Plicht (1998). The OIS age of Spfa-1 (39.5–40.1 ka) seems to coincide with the two calendar AMS ages (39.4 ± 40.1 cal.ka) (Aoki and Arai, 2000).

T8. Petrographic description of tephra layers, p. 22.

F1. OIS and tephrostratigraphy, p. 7.



ACKNOWLEDGMENTS

This research used samples and/or data provided by the Ocean Drilling Program (ODP). ODP is sponsored by the U.S. National Science Foundation (NSF) and participating countries under management of Joint Oceanographic Institutions, Inc. Funding for this research was provided by JSPS Research Fellowships for Young Scientists (number 5568).

REFERENCES

Aoki, K., and Arai, F., 2000. Late Quaternary tephrostratigraphy of maine core KH94-3, LM-8 off Sanriku, Japan. *Quat. Res.,* 39:107–120.

Arai, F., Machida, H., Okumura, K., Miyauchi, T., Soda, T., and Yamagata, K., 1986. Catalog for late Quaternary marker-tephras in Japan, II—tephras occurring in northeast Honshu and Hokkaido. *Geogr. Rep. Tokyo Metropol. Univ.,* 21:223–250.

Aramaki, S., and Ui, T., 1982. Japan. *In* Thorpe, R.S. (Ed.), *Andesites:* New York (Wiley), 259–292.

Bard, E., Arnold, M., Fairbanks, R.G., and Hamelin, B., 1993. ^{230}Th-^{234}U and ^{14}C ages obtained by mass spectrometry on corals. *Radiocarbon,* 35:191–199.

Bard, E., Arnold, M., and Hamelin, B., 1992. Present status of the radiocarbon calibration for the late Pleistocene. *GEOMAR Rep.,* 15:52–53.

Borchardt, G.A., Aruscavage, P.J., and Millard, H.T., Jr., 1972. Correlation of the Bishop ash, a Pleistocene marker bed, using instrumental neutron activation analysis. *J. Sediment. Petrol.,* 42:301–306.

Froggatt, P.C., 1983. Toward a comprehensive upper Quaternary tephra and ignimbrite stratigraphy in New Zealand using electron microprobe analysis of glass shards. *Quat. Res.,* 19:188–200.

————, 1992. Standardization of the chemical analysis of tephra deposits: report of the ICCT working group. *Quat. Int.,* 13/14:93–96.

Furuta, T., Fujioka, K., and Arai, F., 1986. Widespread submarine tephra around Japan, petrographic and chemical property. *Mar. Geol.,* 72:125–146.

Horn, D.R., Delach, M.N., and Horn, B.N., 1969. Distribution of volcanic ash layers and turbidites in the North Pacific. *Geol. Soc. Am. Bull.,* 80:1715–1723.

Kato, S., Yamagata, K., and Okumura, K., 1995. AMS ^{14}C dates of late Quaternary tephra layers erupted from the Shikotsu and Kuttara Volcanoes. *Quat. Res.,* 34:309–313.

Kitagawa, H., and van der Plicht, J., 1998. Atmospheric radiocarbon calibration to 45,000 yr B.P.: late glacial fluctuations and cosmogenic isotope production. *Science,* 279:187–1190.

Machida, H., and Arai, F., 1992. *Atlas of Tephra in and around Japan.* Tokyo (Tokyo Univ. Press).

Machida, H., Arai, F., and Momose, M., 1985. Aso-4 ash: a widespread tephra and its implications to the events of late Pleistocene in and around Japan. *Bull. Volcanol. Soc. Japan, Ser. 2,* 30:49–70.

Martinson, D.G., Pisias, N.G., Hays, J.D., Imbrie, J., Moore, T.C., Jr., and Shackleton, N.J., 1987. Age dating and the orbital theory of the ice ages: development of a high-resolution 0 to 300,000-year chronostratigraphy. *Quat. Res.,* 27:1–29.

Nelson, C.H., Kulm, L.D., Carlson, P.R., and Duncan, J.R., 1968. Mazama ash in the northeastern Pacific. *Science,* 161:47–49.

Sacks, I.S., Suyehiro, K., Acton, G.D., et al., 2000. *Proc. ODP, Init. Repts.,* 186 [CD-ROM]. Available from: Ocean Drilling Program, Texas A&M University, College Station TX 77845-9547, USA.

Sarna-Wojcicki, A.M., 1976. Correlation of late Cenozoic pyroclastic deposits in the Central Coast Ranges of California by means of trace- and minor-element chemistry. *U.S. Geol. Surv. Prof. Pap.*

Shimizu, A., Torii, M., Shiihara, M., and Oda, M., 1997. Age assignments of the bottom of core KH94-3, LM8 PC5 based upon a volcanic ash layer in the lower part. *Kumamoto J. Sci. (Earth Science),* 15:1–7.

Smith, D.G.W., and Westgate, J.A., 1969. Electron probe technique for characterizing pyroclastic deposits. *Earth Planet. Sci. Lett.,* 5:313–319.

Stuiver, M., and Reimer, P.J., 1993. Extended ^{14}C database and revised CALIB 3.0 ^{14}C age calibration. *Radiocarbon,* 35:215–230.

Yanagida, M., 1994. Age of the Shikotsu Pumice Fall 1 deposit (Spfa-1). *Quat. Res.,* 33:205–207.

Yamane, M., and Oba, T., 1999. Paleoceanographic change of the Snriku area during the last 90,000 years based on the analysis of a sediment core (KH94-3, LM-8). *Quat. Res.,* 38:1–16.

Figure F1. Oxygen isotopic stratigraphy and tephrostratigraphy of piston core KH94-3, LM-8 (quoted from Aoki and Arai, 2000). MIS = marine isotope stage.

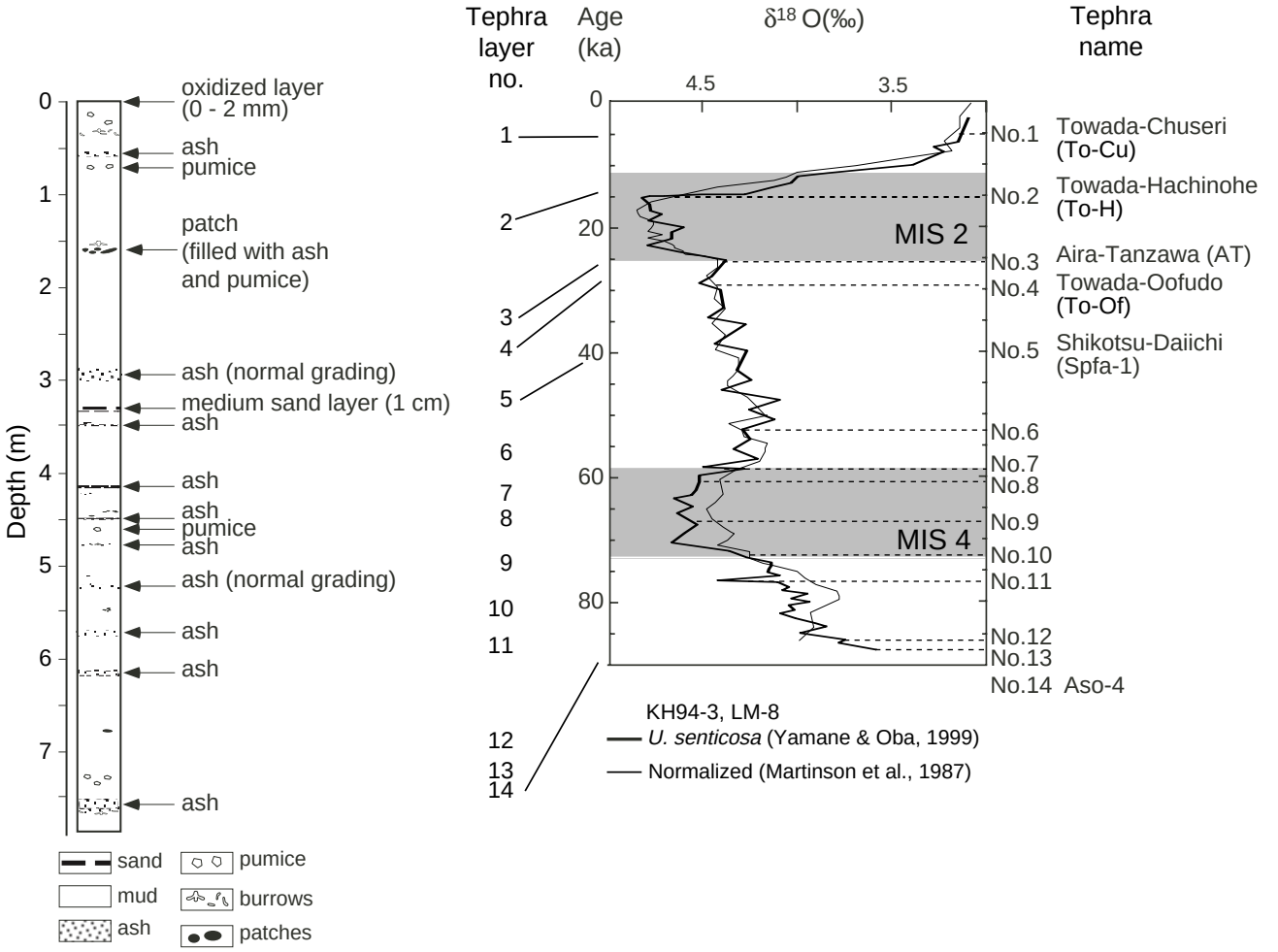


Table T1. List of tephra layers in cores, Hole 1150A. (Continued on next two pages.)

Number	Core, section, interval (cm)	Depth (mbsf) Top	Depth (mbsf) Bottom	Thickness (cm)	Identification	Color	Grain size	Appearance	Lower boundary	Upper boundary	Comments
	186-1150A-										
1	1H-3, 140–145	4.4	4.45	5	Pumice	Gray	Pebble	Two grains			
2	1H-4, 54–57	5.04	5.07	3	Tephra	Dark purple gray	Fine/w granule, coarse	Layer	Sharp	Bioturbated	Pumice scattered below
3	1H-CC, 12–14	7.57	7.59	2	Bioturbated tephra	Dark gray	Fine	Patch			
4	2H-5, 135–142	15.05	15.12	7	Bioturbated tephra	Light gray	Fine	Scattering	Bioturbated	Bioturbated	
5	2H-6, 50–52	15.7	15.72	2	Bioturbated tephra	Dark gray	Fine	Patch			
6	3H-2, 131–139	20.01	20.09	8	Bioturbated tephra	Dark–light gray	Fine	Patch			
7	3H-3, 69–70	20.89	20.9	1	Pumice	Dark gray	Pumice	Single grain			Rounded
8	3H-3, 148–150	21.68	21.7	2	Tephra	Gray	Coarse	Layer	Irregular	Lost by coring	
9	3H-5, 60–73	23.8	23.93	13	Pumice	Light gray	Pebble	Three scattering	Patches	Patches	
10	3H-CC, 22–25	27.27	27.3	3	Tephra	Light gray	Very fine	Layer	Sharp	Sharp	
11	4H-1, 9–13	26.79	26.83	4	Tephra	Gray	Fine	Layer	Erosion base	Fining up	
12	4H-1, 28–31	26.98	27.01	3	Tephra	Dark gray	Fine	Layer	Lost by coring	Irregular	
13	4H-1, 110–130	27.8	28	20	Rework	Gray	Coarse to fine	Layer	Sharp	Irregular	With sand
14	4H-2, 90–95	29.1	29.15	5	Bioturbated tephra	White	Fine	Patches	Heavy bioturbated	Heavy bioturbated	
15	4H-2, 127–137	29.47	29.57	10	Bioturbated tephra	Black	Fine	Patches	Heavy bioturbated	Heavy bioturbated	
16	4H-5, 85–97	33.55	33.67	12	Bioturbated tephra	White	Fine	Patches	Heavy bioturbated	Heavy bioturbated	
17	4H-5, 140–146	34.1	34.16	6	Rework	Dark–light	Coarse to fine	Layer	Sharp	Grading up	With sand
18	4H-6, 23–26	34.43	34.46	3	Bioturbated tephra	Dark gray	Fine	Patch	Heavy bioturbated	Heavy bioturbated	
19	5H-1, 93–94	37.13	37.14	1	Pumice	Gray	Pebble	Two grains			Subangular
20	5H-5, 40–42	42.6	42.62	2	Bioturbated tephra	Dark gray	Fine	Patch			
21	5H-6, 117–118	44.87	44.88	1	Bioturbated tephra	Dark–light gray	Fine	Patch			
22	6H-4, 38–43	50.58	50.63	5	Bioturbated tephra	Light gray	Fine	Patch	Diffuse	Diffuse	
23	6H-4, 98–102	51.18	51.22	4	Tephra	White	Coarse to fine	Layer	Sharp	Undulating	Lamina in upper part
24	6H-CC, 20–24	55.54	55.58	4	Bioturbated tephra	White	Fine	Patch	Diffuse	Diffuse	
25	7H-3, 38–42	58.58	58.62	4	Rework	Dark gray	Coarse to fine	Layer	Sharp	Gradational	With sand
26	7H-4, 30–33	60	60.03	3	Rework	Dark gray	Coarse to fine	Layer	Sharp	Gradational	With sand
27	7H-5, 100–105	62.2	62.25	5	Tephra	Black–white	Coarse to fine	Layer	Sharp	Upward grading	
28	7H-5, 144–150	62.64	62.7	6	Rework	Dark gray	Coarse to fine	Layer	Bioturbated	Upward grading	With sand
29	7H-6, 24–27	62.94	62.97	3	Rework	Dark gray	Coarse	Layer	Erosional sharp	Fining upward	With sand
30	7H-6, 132–137	64.02	64.07	5	Rework	Dark gray	Fine	Layer	Erosional sharp	Gradational	With sand
31	7H-7, 32–37	64.52	64.57	5	Rework	Dark gray	Fine	Bioturbated layer	Eroded and bioturbated	Grading upward	With sand
32	7H-7, 50–53	64.7	64.73	3	Tephra	White	Very fine	Layer	Sharp	As	
33	8H-1, 36–39	65.06	65.09	3	Tephra	Light gray	Very fine	Layer	Sharp	Irregular	
34	8H-1, 50–52	65.2	65.22	2	Rework	Dark gray	Fine to coarse	Layer	Eroded and bioturbated	Irregular	With sand
35	8H-1, 137–138	66.07	66.08	1	Tephra	Light gray	Very fine	Thin layer	Not clear	Not clear	
36	8H-4, 88–92	70.08	70.12	4	Rework	Dark gray	Fine	Layer	Erosion base	Grading upward	With sand
37	8H-4, 126–128	70.46	70.48	2	Tephra	Light gray	Fine	Layer	Scoured	Gradational	
38	8H-5, 35–70	71.05	71.4	35	Pumice	Dark gray	Pebble	Mottling			With sand
39	8H-5, 86–90	71.56	71.6	4	Rework	Dark gray	Very fine	Layer	Erosion base	Grading up	With sand
40	8H-6, 20–25	72.4	72.45	5	Bioturbated tephra	Dark greenish gray	Fine	Patch			With sand
41	8H-6, 46–51	72.66	72.71	5	Pumice	Light gray–gray		Layer	Scoured	Scoured	With sand
42	9H-1, 93–97	75.13	75.17	4	Rework	Dark gray	Coarse	Layer	Erosional base	Fining up	With sand
43	9H-2, 60–69	76.3	76.39	9	Rework	Dark gray	Fine	Bioturbated layer	Discontinuous		With sand
44	9H-2, 98–103	76.68	76.73	5	Tephra	White	Very fine	Layer	Sharp	Irregular	

Table T1 (continued).

Number	Core, section, interval (cm)	Depth (mbsf) Top	Depth (mbsf) Bottom	Thickness (cm)	Identification	Color	Grain size	Appearance	Lower boundary	Upper boundary	Comments
45	9H-3, 0–7	77.2	77.27	7	Tephra	Dark gray	Fine	Layer	Sharp	Lost	
46	9H-4, 95–99	79.63	79.67	4	Tephra	Light gray	Very fine	Layer	Scoured	Scoured	
47	9H-6, 95–107	82.63	82.75	12	Tephra	White	Very fine		Mottled	Mottled	
48	10H-4, 67–68	88	88.01	1	Ash?	Gray	Fine		Scoured	Scoured	
49	10H-5, 25–27	89.01	89.03	2	Ash?	White	Fine		Mottled		
50	10H-5, 108–109	89.84	89.85	1	Ash?	Light gray	Fine		Discontinuous		
51	10H-5, 135–137	90.11	90.13	2	Ash	Light gray	Fine		Patches		
52	10H-6, 125–130	91.46	91.51	5	A lot volume glass silt	Light olive	Fine		Ghost		
53	10H-7, 16–17	91.87	91.88	1		White	Fine				
54	10H-7, 52–53	92.23	92.24	1	Ash	White gray	Fine		Sharp	Sharp	
55	11H-5, 128–134	99.37	99.43	6	*	Dark gray	Coarse		Not Sharp	Fining upward	
56	11H-1, 104–108	94.24	94.28	4	Rework	Gray	Fine		Erosional base	Scoured	
57	11H-1, 134–150	94.54	94.7	16	Rework	Dark gray–light gray	Fine to coarse		Lost by coring	Fining upward	
58	11H-3, 24–30	96.44	96.5	6		Gray	Fine		Heavy bioturbated	Heavy bioturbated	
59	11H-3, 99–103	97.19	97.23	4	Tephra	Gray			Heavy bioturbated	Heavy bioturbated	
60	11H-4, 66–67	97.96	97.97	1		Light gray	Fine		Heavy bioturbated	Heavy bioturbated	
61	11H-5, 128–134	99.37	99.43	6	Rework	White–dark	Fine to coarse		Not sharp	Fining upward	
62	11H-7, 90–93	101.77	101.8	3	Rework	Light gray			Fractured by coring	Fractured by coring	With sand
63	12H-2, 40–43	104.6	104.63	3		Light gray	Coarse		Erosional base		
64	12H-3, 82–85	106.15	106.18	3	Rework	Gray	Coarse		Sharp	Fining upward	
65	12H-3, 146	106.79	106.83			Light gray	Sharp		Diffuse		
66	12H-4, 2	106.83	106.85	6							
67	12H-4, 68–71	107.51	107.54	3	Rework	White	Fine		Sharp	Diffuse	
68	15X-2, 116–118	128.66	128.68	2	Rework	Gray	Fine		Erosional sharp base	Scoured	
69	18X-1, 2–6	154.82	154.86	4	Rework	Gray	Coarse to fine		Erosional sharp base	Scoured	
70	18X-3, 115–117	158.95	158.97	2		Light–dark gray	Coarse to fine		Sharp	Fining upward	
71	18X-4, 29–35	159.59	159.65	6			Pumice				
72	18X-4, 134–137	160.64	160.67	3		Gray	Fine		Sharp	Fining upward	
73	21X-2, 45–47	185.55	185.57	2		Light gray	Fine		Bioturbated	Bioturbated	
74	23X-2, 35–46	204.51	204.62	11	Rework	Dark–light gray	Coarse to fine		Erosional sharp base	Fining up, diffuse	
75	23X-7, 15–20	211.29	211.34	5	Tephra	White	Very Fine		Voids from gas		
76	25X-7, 68–78	231.05	231.15	10	Rework	Black–white			No sharp base	Fining upward	
77	26X-4, 100–104	237.4	237.44	4			Pumice (3–10 mm)				
78	27X-4, 90–93	246.9	246.93	3	Rework	Dark gray	Fine		Erosional sharp	Fining up to light color and to clay	
79	28X-4, 33–34	255.92	255.93	1			Pumice (3–10 mm)				
80	30X-2, 106–117	272.96	273.07	11			Pumice (granule–pebble)				
81	32X-4, 120–123	295.4	295.43			White-green			Sharp	No clear	
82	34X-5, 47–51	315.57	315.61	4		Dark gray	Coarse to fine		Sharp	Sharp	
83	37X-3, 58–62	341.58	341.62	4		Dark gray	Very fine to fine		Sharp		
84	38X-1, 146–149	349.06	349.09	3		Dark gray	Fine		Sharp (no erosional)	Sharp	
85	40X-6, 25–30	374.4	374.45	5		Dark gray–gray			Erosional base	Fining upward	

Table T1 (continued).

Number	Core, section, interval (cm)	Depth (mbsf) Top	Depth (mbsf) Bottom	Thickness (cm)	Identification	Color	Grain size	Appearance	Lower boundary	Upper boundary	Comments
86	41X-1, 72–73	377.12	377.13	1	Tephra	Light gray–white	Fine		Sharp	Sharp	Tephra
87	42X-1, 96–98	386.96	386.98	2		Light gray–white	Fine		Sharp	Sharp	
88	42X-7, 70–72	394.62	394.64	2		Dark gray	Coarse		Sharp	Fining upward	

Table T2. List of tephra layers in cores, Hole 1151A. (This table is available in an **oversized format**.)

Table T3. List of tephra in cores, Hole 1151C. (Continued on next two pages.)

Number	Core, section, interval (cm)	Depth (mbsf) Top	Depth (mbsf) Bottom	Identification	Color	Grain size	Appearance	Lower boundary	Upper boundary	Comments
	186-1151C-									
1	1H-2, 10.0–10.2	1.60	1.60	Pumice	Light gray	Granule	Grain			
2	1H-2, 18.0–19.0	1.68	1.69	Pumice	Light gray	Pebble	Grains			Rounded
3	1H-2, 32.0–33.0	1.82	1.83	Pumice	Light gray	Pebble	Grain			Rounded
4	1H-2, 39.0–39.5	1.89	1.90	Pumice	Light gray	Pebble	Grain			Rounded
5	2H-1, 100.0–101.0	3.20	3.21	Pumice	Light gray	Pebble	Grain			Subrounded
6	2H-1, 137.0–138.0	3.57	3.58	Pumice	Light gray	Granule	Grains			
7	2H-3, 40.0–40.5	5.60	5.61	Pumice	Light gray	Granule	Grains			Rounded
8	2H-3, 115.0–115.5	6.35	6.36	Pumice	Light gray	Granule	Grain			Rounded
9	2H-5, 14.0–18.0	8.34	8.38	Tephra	Greenish white	Fine	Diffuse layer	Diffuse	Diffuse	With gray silt
10	2H-5, 20.0–20.5	8.40	8.40	Bioturbated ash	White	Fine	Patch			
11	2H-6, 115.0–115.5	10.85	10.85	Pumice	Light gray	Granule	Grain			
12	2H-7, 31.0–34.0	11.51	11.54	Bioturbated ash	Gray	Silt	Thin patches			With black and white grains
13	3H-1, 40.0–44.0	12.10	12.14	Tephra	Gray	Very fine	Layer	Sharp	Inclined	Slightly lightening
14	3H-3, 110.0–120.0	15.80	15.90	Bioturbated ash	White	Very fine	Small patches			
15	3H-3, 111.0–111.5	15.81	15.81	Pumice	White	Granule	Grain			Rounded
16	3H-4, 111.0–112.0	17.31	17.32	Bioturbated ash	Light gray	Silt	Patches			Flat
17	4H-3, 86.0–90.0	25.07	25.11	Rework	Dark gray	Sand	Layer	Sharp	Diffuse	With sand
18	4H-3, 92.0–99.0	25.13	25.20	Rework	Gray	Coarse	Layer	Sharp	Gradational	Light gray in top and bottom, with sand
19	4H-4, 38.0–39.0	26.11	26.12	Bioturbated ash	Light gray	Very fine	Diffuse patches			
20	4H-6, 137.0–140.0	30.14	30.17	Bioturbated ash	Light gray	Sand	Patches			With white and black grains
21	4H-7, 30.0–31.0	30.57	30.58	Bioturbated ash	White	Very fine	Patch			
22	5H-1, 142.0–150.0	32.12	32.20	Tephra	Light gray	Silt	Layer	Wavy erosional base	Diffuse	Lightening upward
23	5H-3, 75.0–78.0	34.45	34.48	Bioturbated ash	White	Silt	Small patches			
24	5H-4, 42.0–56.0	35.62	35.76	Tephra	Light gray	Fine	Layer	Scoured	Diffuse	
25	5H-4, 78.0–79.0	35.98	35.99	Pumice	Light gray	Granule	Grain			Rounded
26	5H-4, 144.0–147.0	36.64	36.67	Bioturbated ash	White	Fine	Diffuse patch			
27	5H-5, 7.0–8.0	36.77	36.78	Bioturbated ash	White	Fine	Patch			
28	5H-7, 16.0–17.0	39.56	39.57	Bioturbated ash	Bright white	Very fine	Diffuse patch			Flat
29	5H-CC, 11.0–14.0	40.34	40.37	Bioturbated ash	Greenish light gray	Diffuse patch				
30	6H-2, 24.0–24.5	41.94	41.95	Pumice	Light gray	Granule	Grain			Rounded
31	6H-2, 63.0–63.5	42.33	42.34	Pumice	Light gray	Granule	Grain			Rounded
32	6H-3, 64.0–72.0	43.84	43.92	Tephra	White	Coarse	Layer	Sharp	Gradational	Grain in lower part
33	6H-5, 25.0–25.3	46.45	46.45	Rework	Gray		Thin layer			
34	6H-5, 30.0–30.3	46.50	46.50	Rework	Gray		Thin layer			
35	6H-5, 57.0–62.0	46.77	46.82	Bioturbated ash	White	Fine	Diffuse patches			
36	6H-6, 48.0–48.2	48.18	48.18	Pumice	Light gray	Granule	Grain			Rounded
37	6H-6, 64.0–70.0	48.34	48.40	Bioturbated ash	White		Mottled patches			
38	7H-1, 124.0–129.0	50.94	50.99	Tephra	White	Fine	Layer	Diffuse	Diffuse	
39	7H-3, 38.0–44.0	53.08	53.14	Bioturbated ash	White	Fine	Mottled			
40	7H-4, 80.0–84.0	55.00	55.04	Tephra	Greenish gray	Fine	Sharp	Diffuse		
41	7H-4, 116.0–124.0	55.36	55.44	Bioturbated ash	White		Mottled			
42	7H-5, 25.0–26.2	55.95	55.96	Pumice		Pebble	Grain			Rounded
43	7H-5, 70.0–72.0	56.40	56.42	Tephra	White	Fine	Layer	Diffuse	Diffuse	

Table T3 (continued).

Number	Core, section, interval (cm)	Depth (mbsf) Top	Depth (mbsf) Bottom	Identification	Color	Grain size	Appearance	Lower boundary	Upper boundary	Comments
44	7H-5, 124.0–126.0	56.94	56.96	Bioturbated ash	White		Mottled			
45	7H-CC, 6.0–8.0	59.37	59.39	Pumice		Pebble	Grains			Subrounded, with silt
46	8H-1, 19.0–21.0	59.39	59.41	Bioturbated ash	White	Fine	Mottled and scattered			
47	8H-2, 115.0–130.0	61.85	62.00	Pumice	White, gray	Granule	Scattering			Rounded to subrounded, disturbed by coring
48	8H-3, 68.0–70.0	62.88	62.90	Bioturbated ash	White	Fine	Patches			
49	8H-4, 82.0–85.0	64.52	64.55	Tephra	White	Coarse–fine	Layer	Sharp, coarse	Diffuse	White ash scattered below layer
50	8H-5, 59.0–69.0	65.79	65.89	Bioturbated ash	White	Fine	Small patches			
51	8H-7, 18.0–22.0	68.38	68.42	Tephra	Dark gray–greenish white	Sand–fine	Sharp	Very diffuse		
52	8H-7, 40.0–42.0	68.60	68.62	Bioturbated ash	Bright white		Patches			
53	8H-7, 19.0–80.0	68.39	69.00	Tephra	White, light gray	Layer	Sharp	Diffuse		
54	8H-CC, 18.0–24.0	69.21	69.27	Rework	Gray	Silt	Layer	Sharp	Gradational	Homogenous in color
55	9H-1, 5.0–16.0	68.75	68.86	Tephra	Dark gray–white	Coarse to fine	Layer	Inclined	Diffuse	
56	9H-1, 137.0–140.0	70.07	70.10	Bioturbated ash	Gray	Silt	Patch			
57	9H-2, 104.0–110.0	71.24	71.30	Bioturbated ash	White	Silt	Patches			
58	9H-3, 14.0–19.0	71.84	71.89	Tephra		Sand	Layer	Sharp	Gradational	
59	9H-4, 27.0–29.0	73.47	73.49	Bioturbated ash	White		Small diffuse patches			
60	9H-4, 138.0–142.0	74.58	74.62	Bioturbated ash	Black and white	Patches				
61	9H-4, 146.0–146.2	74.66	74.66	Pumice		Granule	Grain			
62	9H-5, 140.0–150.0	76.10	76.20	Tephra	Blight white		Layer	Sharp	Diffuse	Some mottling below layer
63	9H-6, 76.0–78.0	76.96	76.98	Bioturbated ash	White		Diffuse patch			
64	9H-6, 81.0–84.0	77.01	77.04	Bioturbated ash	White		Patch			
65	9H-6, 98.0–99.0	77.18	77.19	Pumice		Pebble	Grain			
66	10H-1, 27.0–28.0	78.47	78.48	Bioturbated ash	Light gray		Patches			
67	10H-1, 55.0–57.0	78.75	78.77	Pumice		Granule	Grains			
68	10H-1, 119.0–123.0	79.39	79.43	Tephra	White	Very fine	Layer	Sharp	Irregular	With prefall ash
69	10H-1, 133.0–137.0	79.53	79.57	Tephra	White	Very fine	Layer	Sharp	Irregular	
70	10H-2, 27.0–47.0	79.97	80.17	Pumice	Gray	Granule	Scattering			
71	10H-4, 15.0–18.0	82.85	82.88	Tephra	Light gray	Fine	Layer	Sharp	Irregular	With prefall, and patch above
72	10H-4, 117.0–120.0	83.87	83.90	Tephra	Light gray–gray	Fine–coarse	Layer	Sharp	Sharp	With very fine light gray base part
73	10H-5, 68.0–70.0	84.88	84.90	Rework	Light gray–gray	Fine	Layer	Irregular	Irregular	With sand
74	10H-6, 15.0–17.0	85.85	85.87	Pumice	Light gray	Granule	Grains			
75	10H-6, 87.0–88.0	86.57	86.58	Pumice	Gray	Pebble	Grain			Subrounded
76	10H-6, 133.0–136.0	87.03	87.06	Pumice	Gray	Granule and pebble	Grains			Subangular
77	10H-7, 21.0–21.5	87.41	87.42	Pumice	Gray	Granule	Grain			Subrounded
78	10H-7, 29.0–35.0	87.49	87.55	Pumice	Light gray–gray	Granule	Scattered layer			
79	10H-CC, 8.0–19.0	88.17	88.28	Bioturbated ash	Light gray	Very fine	Small patches			
80	10H-CC, 24.0–26.0	88.33	88.35	Pumice	Light gray	Pebble and granule	Grains			
81	11H-2, 34.0–35.0	89.54	89.55	Pumice	Light gray	Granule	Grain			

Table T3 (continued).

Number	Core, section, interval (cm)	Depth (mbsf) Top	Depth (mbsf) Bottom	Identification	Color	Grain size	Appearance	Lower boundary	Upper boundary	Comments
82	11H-2, 46.0–50.0	89.66	89.70	Bioturbated ash	Light gray	Fine	Patches			
83	11H-3, 38.0–38.5	91.08	91.09	Pumice	Gray	Granule	Grain			Rounded
84	11H-3, 76.0–80.0	91.46	91.50	Pumice	Light gray	Granule	Scattered layer			Subrounded, with green small patch
85	11H-4, 134.0–135.0	93.54	93.55	Pumice	Gray	Granule	Grain			Subrounded
86	11H-5, 13.0–13.3	93.83	93.83	Pumice	Gray	Granule	Grain			Rounded
87	11H-5, 21.0–22.0	93.91	93.92	Pumice	Gray	Granule	Grains			Rounded
88	11H-5, 44.0–44.5	94.14	94.14	Bioturbated ash	Yellowish gray	Fine	Patch			
89	11H-5, 46.0–53.0	94.16	94.23	Tephra	White–light gray	Very fine–fine	Layer	Sharp	Irregular	With two parts
90	11H-5, 53.0–55.0	94.23	94.25	Rework	Dark-light gray	Fine–medium	Layer	Sharp	Grading	
91	11H-5, 60.0–60.5	94.30	94.31	Pumice	Gray	Pebble	Grain			Angular
92	11H-5, 64.0–70.0	94.34	94.40	Bioturbated ash	Light gray	Fine	Patch			With glauconitic patch
93	11H-5, 80.0–80.5	94.50	94.51	Pumice	Gray	Granule	Grain			
94	11H-6, 11.0–15.0	95.31	95.35	Bioturbated ash	Light gray		Patch			
95	11H-6, 20.0–24.0	95.40	95.44	Rework	Light–brownish and white	Fine	Layer	Erosional base	Irregular	Two parts
96	11H-6, 62.0–64.0	95.82	95.84	Bioturbated ash	Light gray	Very fine	Patch			
97	11H-6, 117.0–119.0	96.37	96.39	Bioturbated ash	Light gray	Fine	Patch			

Table T4. List of volcanic origin layers in cores, Hole 1151D. (Continued on next three pages.)

Number	Core, section, interval (cm)	Depth (mbsf) Top	Depth (mbsf) Bottom	Identification	Color	Grain size	Appearance	Lower boundary	Upper boundary	Comments
	186-1151D-									
1	1H-1, 110.5–111.0	1.11	1.11	Pumice	Gray	Pebble	Grain			Angular
2	1H-1, 125.0–125.4	1.25	1.25	Pumice	Gray	Granule	Grain			Rounded
3	1H-1, 131.0–131.4	1.31	1.31	Pumice	Gray	Granule	Grain			Rounded
4	1H-1, 137.0–139.0	1.37	1.39	Tephra	Gray	Fine	Discontinuous layer			With Pumice
5	1H-2, 56.0–60.0	2.06	2.1	Pumice	Gray	Granule–pebble	Grains			Rounded
6	1H-2, 72.0–73.0	2.22	2.23	Pumice	Light gray	Pebble	Grains			Subangular
7	1H-2, 80.0–82.0	2.30	2.32	Pumice	Light gray	Pebble	Grains			Angular
8	1H-2, 89.0–89.5	2.39	2.4	Pumice	Gray	Granule	Grain			
9	1H-2, 97.0–97.5	2.47	2.48	Pumice	Gray	Granule	Grain			
10	1H-2, 108.0–114.0	2.58	2.64	Pumice	Gray	Pebble	Grains			Rounded–subrounded
11	1H-2, 117.0–118.0	2.67	2.68	Pumice	Greenish gray	Pebble	Grain			Rounded
12	1H-3, 44.0–45.0	3.44	3.45	Pumice	Light gray	Pebble	Grains			Angular
13	1H-3, 90.0–92.0	3.90	3.92	Pumice	Dark greenish gray	Granule	Grains			With sand
14	1H-4, 14.0–15.0	4.64	4.65	Pumice	Gray	Pebble	Grain			Angular
15	1H-4, 87.0–89.0	5.37	5.39	Pumice	Dark gray	Pebble	Grain			Subangular
16	1H-4, 121.0–121.5	5.71	5.72	Pumice	Gray	Granule	Grain			
17	1H-4, 149.0–149.5	5.99	6	Pumice	Gray	Granule	Grain			
18	1H-5, 39.0–39.5	6.39	6.4	Pumice	Dark gray	Granule	Grain			Angular
19	1H-5, 50.0–50.5	6.50	6.51	Pumice	Gray	Granule	Grain			Angular
20	1H-5, 56.0–56.5	6.56	6.57	Pumice	Gray	Granule	Grains			Angular, with sand
21	1H-5, 72.0–72.5	6.72	6.73	Pumice	Gray	Granule	Grain			Angular
22	2H-1, 85.0–85.7	8.35	8.36	Pumice	Gray	Pebble	Grain			Angular
23	2H-2, 103.0–103.5	10.03	10.04	Pumice	Gray	Pebble	Grain			Subangular
24	2H-2, 104.0–106.0	10.04	10.06	Tephra	White	Fine	Bioturbated layer	Bioturbated	Bioturbated	
25	2H-2, 118.0–118.5	10.18	10.19	Pumice	Light gray	Pebble	Grain			
26	2H-3, 98.0–107.0	11.48	11.57	Rework	Light–dark gray	Medium	Layer	Erosional sharp	Sharp	With sand
27	2H-4, 22.0–29.0	12.22	12.29	Pumice	Gray	Granule–pebble	Scattering			Angular
28	2H-4, 42.0–43.0	12.42	12.43	Bioturbated ash	Light gray	Medium	Patches			With sand
29	2H-6, 34.0–34.7	15.34	15.35	Pumice	Gray	Pebble	Grain			
30	2H-6, 60.0–60.5	15.60	15.61	Pumice	Gray	Pebble	Grain			
31	3H-6, 132.0–137.0	16.32	16.37	Bioturbated ash	Dark gray	Fine	Patches			
32	4H-1, 29.0–31.0	26.79	26.81	Pumice	Dark brownish gray	Pebble	Grains			Rounded
33	4H-1, 37.0–37.5	26.87	26.88	Pumice	Light gray	Granule	Grain			Rounded
34	4H-1, 57.0–57.5	27.07	27.08	Pumice	Light gray	Granule	Grain			Subrounded
35	4H-1, 97.0–97.5	27.47	27.48	Pumice	Dark gray	Pebble	Grain			Subrounded
36	4H-2, 24.0–24.5	28.24	28.25	Pumice	Dark gray	Granule	Grain			Subrounded
37	4H-2, 84.0–90.0	28.84	28.9	Pumice	Dark gray	Granule	Layer			
38	4H-3, 90.0–93.0	30.40	30.43	Tephra	Light gray–gray	Medium	Layer	Sharp	Sharp	Dark color in bottom
39	4H-5, 24.0–32.0	32.74	32.82	Tephra	Yellowish gray	Fine	Layer	Very sharp	Sharp	Biotite included, prefall
40	4H-7, 65.0–68.0	36.15	36.18	Tephra	Light gray	Fine–medium	Layer	Sharp	Irregular	Biotite included
41	4H-CC, 8.0–9.0	36.26	36.27	Bioturbated ash	Light gray	Fine–medium	Patch			
42	5H-1, 81.0–85.0	36.81	36.85	Bioturbated ash	Light gray	Very Fine	Patch			
43	5H-2, 85.0–86.0	38.35	38.36	Bioturbated ash	Brownish gray	Fine	Patch			
44	5H-3, 80.0–88.0	39.80	39.88	Pumice	Dark gray	Granule	Grains			Angular

Table T4 (continued).

Number	Core, section, interval (cm)	Depth (mbsf) Top	Depth (mbsf) Bottom	Identification	Color	Grain size	Appearance	Lower boundary	Upper boundary	Comments
45	5H-4, 42.0–44.0	40.92	40.94	Pumice	Dark gray	Pebble	Grains			Subangular
46	5H-4, 92.0–98.0	41.42	41.48	Bioturbated ash	Light yellowish gray	Very fine	Patches			
47	5H-4, 102.0–105.0	41.52	41.55	Pumice	Gray	Pebble	Grains			Angular
48	5H-5, 32.0–35.0	42.32	42.35	Tephra	Light yellowish gray	Very fine	Diffuse layer	No clear	No clear	Lower is dark gray
49	6H-1, 5.0–6.0	45.55	45.56	Bioturbated ash	Light gray	Very fine	Patch			
50	6H-1, 70.0–88.0	46.20	46.38	Bioturbated ash	Light gray	Fine	Patch			
51	6H-2, 32.0–32.5	47.32	47.33	Pumice	Gray	Pebble	Grain			Subrounded
52	6H-2, 80.0–89.0	47.80	47.89	Pumice	Light gray	Granule	Scattered			Rounded
53	6H-2, 16.0–20.0	47.16	47.2	Pumice	Yellowish gray–gray	Granule	Grains			
54	6H-4, 24.0–28.0	50.24	50.28	Bioturbated ash	Light yellowish gray	Very fine–fine	Patches			
55	6H-5, 24.0–30.0	51.74	51.8	Bioturbated ash	Light gray	Fine	Patches			
56	6H-5, 42.0–45.0	51.92	51.95	Bioturbated ash	Light gray	Fine	Patches			
57	6H-5, 48.0–62.0	51.98	52.12	Bioturbated ash	Light gray–gray	Fine	Patches			With silt
58	6H-5, 62.0–62.8	52.12	52.13	Pumice	Gray	Pebble	Grain			Angular
59	6H-5, 86.0–88.0	52.36	52.38	Pumice	Dark gray–gray	Granule	Accumulation			
60	6H-6, 36.0–36.5	53.36	53.37	Pumice	Dark gray	Pebble	Grain			Angular
61	6H-6, 56.0–64.0	53.56	53.64	Bioturbated ash	Light gray	Fine	Patches			
62	6H-7, 55.0–55.5	55.05	55.06	Pumice	Yellowish gray	Granule	Grain			
63	7H-2, 17.0–23.0	56.77	56.83	Tephra	Light gray–gray	Very fine	Layer	Sharp	Irregular	Vitric
64	7H-2, 54.0–56.0	57.14	57.16	Rework	Yellowish light gray–dark gray	Fine	Layer	Sharp	Diffuse	Dark in bottom
65	7H-2, 72.0–77.0	57.32	57.37	Pumice	Yellowish and dark gray	Granule	Scattering			
66	7H-2, 90.0–90.5	57.50	57.51	Pumice	Greenish gray	Pebble	Grain			
67	7H-3, 10.0–11.0	58.10	58.11	Bioturbated ash	Dark gray	Fine	Diffuse patches			
68	7H-3, 13.0–15.0	58.13	58.15	Tephra	Light yellowish gray	Fine	Irregular layer	Irregular	Irregular	
69	7H-3, 61.0–64.0	58.61	58.64	Pumice	Dark gray	Pebble	Grain			Subrounded, with silt
70	7H-3, 108.0–111.0	59.08	59.11	Pumice	Dark gray–gray	Granule	Accumulation			
71	7H-4, 17.0–37.0	59.67	59.87	Pumice	Light gray	Granule	Scattering			
72	7H-5, 70.0–93.0	61.70	61.93	Bioturbated ash	Light gray	Silt	Small patches			
73	7H-6, 6.0–10.0	62.56	62.6	Rework	Gray–dark gray	Medium	Layer	Erosional base	Fining upward	With sand
74	7H-6, 10.0–11.0	62.60	62.61	Bioturbated ash	Yellowish light gray	Fine	Patch			
75	7H-6, 59.0–62.0	63.09	63.12	Pumice	Dark gray	Granule	Scattering			
76	7H-7, 2.0–8.0	64.02	64.08	Pumice	Yellowish gray	Granule	Scattering			
77	7H-7, 41.0–44.0	64.41	64.44	Pumice	Gray–dark gray	Granule	Grains			
78	8H-1, 0.0–4.0	64.50	64.54	Bioturbated ash	Gray	Very fine	Patches			
79	8H-1, 7.0–8.0	64.57	64.58	Bioturbated ash	Gray	Very fine	Small patches			
80	8H-2, 31.0–36.0	66.31	66.36	Tephra	Dark–light gray	Coarse–very fine	Layer	Sharp	Diffuse	3 Layers
81	8H-3, 20.0–25.0	67.70	67.75	Bioturbated ash	Yellowish light gray	Fine	Patches			
82	8H-3, 83.0–84.0	68.33	68.34	Bioturbated ash	Light gray	Fine	Patch			
83	8H-4, 34.0–35.0	69.34	69.35	Pumice	Dark gray	Pebble	2 Grains			
84	8H-4, 40.0–40.5	69.40	69.41	Pumice	Dark gray	Pebble	Grain			
85	8H-4, 48.0–50.0	69.48	69.5	Pumice	Dark gray	Pebble	Grains			
86	8H-5, 4.0–5.0	70.54	70.55	Bioturbated ash	Yellowish gray	Fine	Patches			With glauconite
87	8H-5, 5.0–26.0	70.55	70.76	Pumice	Light gray	Granule	Scattered			
88	8H-5, 20.0–27.0	70.70	70.77	Pumice	Light–yellowish gray	Fine	Patches			
89	8H-5, 48.0–49.0	70.98	70.99	Tephra	Light gray–gray	Fine	Thin layer	Irregular	Irregular	
90	8H-5, 50.0–75.0	71.00	71.25	Pumice	Yellowish light gray	Granule	Scattering			

Table T4 (continued).

Number	Core, section, interval (cm)	Depth (mbsf) Top	Depth (mbsf) Bottom	Identification	Color	Grain size	Appearance	Lower boundary	Upper boundary	Comments
91	8H-5, 76.0–80.0	71.26	71.3	Tephra	Gray-light gray	Fine	Layer	Very sharp	Fining, diffuse	
92	8H-5, 80.0–95.0	71.30	71.45	Pumice	Light–yellowish light gray	Fine-granule	Scattering			With ash
93	8H-5, 95.0–106.0	71.45	71.56	Tephra	Light–yellowish light gray	Coarse –very fine	Layer			Coarse dark gray sand-size in lower, fining up to very fine, light gray ash
94	8H-6, 73.0–75.0	72.73	72.75	Tephra	Gray	Very Fine	Layer	Sharp	Sharp	
95	8H-7, 43.0–45.0	73.93	73.95	Tephra	Yellowish light gray	Fine	Layer	Sharp	Scoured	
96	8H-CC, 12.0–17.0	74.51	74.56	Tephra	Gray–yellowish light gray	Coarse	Layer	Sharp	Scoured	Yellowish in top, gray-light gray in bottom
97	9H-1, 4.0–8.0	74.04	74.08	Patches	Light yellowish gray	Fine	Patches			
98	9H-1, 15.0–15.5	74.15	74.16	Pumice	Greenish gray	Granule	Grain			
99	9H-1, 40.0–73.0	74.40	74.73	Pumice	Dark gray, greenish gray	Granule	Scattering			With sand
100	9H-1, 110.0–117.0	75.10	75.17	Pumice	Yellowish light gray	Granule	Scattering			
101	9H-1, 143.0–145.0	75.43	75.45	Pumice	Dark gray	Granule	Grains			
102	9H-2, 55.0–61.0	76.05	76.11	Tephra	Dark gray–gray	Medium–very fine	Bioturbated layer			
103	9H-2, 110.0–110.5	76.60	76.61	Pumice	Dark gray	Pebble	Grain			Angular
104	9H-2, 118.0–120.0	76.68	76.7	Pumice	Dark gray	Pebble	Grains			Angular
105	9H-2, 126.0–144.0	76.76	76.94	Pumice	Dark gray	Granule	Scattered			Rounded
106	9H-3, 9.0–9.5	77.09	77.1	Pumice	Light gray	Granule	Grain			
107	9H-3, 17.0–18.0	77.17	77.18	Pumice	Dark gray	Pebble	Grains			Angular
108	9H-3, 44.0–45.0	77.44	77.45	Pumice	Dark gray	Pebble	Grain			Angular
109	9H-3, 58.0–59.0	77.58	77.59	Pumice	Greenish gray	Granule	Grains			Angular
110	9H-3, 66.0–69.0	77.66	77.69	Pumice	Dark gray–gray	Pebble	Grains			
111	9H-3, 66.0–69.0	77.66	77.69	Bioturbated ash	Yellowish light gray	Fine	Patches			
112	9H-4, 0.0–5.0	78.48	78.53	Tephra	Yellowish light gray	Fine	Layer	Scoured	Scoured	
113	9H-4, 10.0–10.5	78.58	78.59	Pumice	Light gray	Granule	Grain			Rounded
114	9H-4, 29.0–29.5	78.77	78.78	Pumice	Light gray	Granule	Grain			Rounded
115	9H-4, 73.0–74.0	79.21	79.22	Pumice	Dark gray	Pebble	Grains			Angular
116	9H-4, 136.0–136.5	79.84	79.85	Pumice	Granule	Granule	Grain			
117	9H-5, 5.0–5.5	80.03	80.04	Pumice	Light gray	Pebble	Grain			
118	9H-5, 9.0–10.0	80.07	80.08	Pumice	Light gray–gray		Grains			
119	9H-5, 36.0–42.0	80.34	80.4	Tephra	Light-dark gray	Coarse	Layer	Sharp	Sharp	
120	9H-5, 98.0–99.0	80.96	80.97	Pumice	Light gray	Granule	Grains			Rounded
121	9H-5, 101.0–101.5	80.99	81	Pumice	Dark gray	Pebble	Grain			Subrounded
122	9H-5, 126.0–128.0	81.24	81.26	Pumice	Light gray	Pebble	Grain			Subangular
123	9H-6, 33.0–33.5	81.63	81.64	Pumice	Light gray	Granule	Grain			
124	9H-6, 45.0–45.5	81.75	81.76	Pumice	Dark gray	Pebble	Grain			Subrounded
125	9H-6, 118.0–118.5	82.48	82.49	Pumice	Dark gray	Pebble	Grain			With silty patches
126	9H-7, 13.0–17.0	82.76	82.8	Tephra	White	Very fine	Layer	Sharp	Irregular	
127	9H-CC, 18.0–20.0	83.37	83.39	Pumice	Light gray	Granule	Scattered			
128	10H-1, 93.0–96.0	84.43	84.46	Tephra	Yellowish light gray	Very fine	Layer	Scoured	Scoured	
129	10H-2, 18.0–18.5	85.18	85.19	Pumice	Dark gray	Granule	Grain			
130	10H-2, 33.0–34.0	85.33	85.34	Bioturbated ash	Light gray	Very fine	Patches			With silty patches
131	10H-2, 110.0–114.0	86.10	86.14	Tephra	Light yellowish gray	Very fine	Layer	Bioturbated, irregular	Bioturbated, irregular	
132	10H-3, 93.0–93.5	87.43	87.44	Pumice	Light gray	Granule	Grain			
133	10H-3, 104.0–105.0	87.54	87.55	Pumice	Light gray	Granule–pebble	Layer			

Table T4 (continued).

Number	Core, section, interval (cm)	Depth (mbsf) Top	Depth (mbsf) Bottom	Identification	Color	Grain size	Appearance	Lower boundary	Upper boundary	Comments
134	10H-3, 109.0–110.0	87.59	87.6	Pumice	Light gray	Granule	Grains			With sand
135	10H-3, 127.0–127.5	87.77	87.78	Pumice	Light gray	Granule	Grain			
136	10H-4, 13.0–14.0	88.13	88.14	Pumice	Light–greenish gray	Granule	Grains			
137	10H-4, 48.0–49.0	88.48	88.49	Pumice	Light gray	Pebble	Grains			
138	10H-4, 82.0–84.0	88.82	88.84	Rework	Dark gray	Sandy silt	Layer	Sharp	Diffuse	With sand
139	10H-5, 12.0–15.0	89.62	89.65	Tephra	Light gray–gray	Fine	Layer	Scoured	Scoured	
140	10H-5, 25.0–26.0	89.75	89.76	Tephra	Light brownish gray with gray	Very fine	Layer	Sharp	Scoured	
141	10H-5, 34.0–34.5	89.84	89.85	Pumice	Light gray	Pebble	Grain			
142	10H-6, 74.0–77.0	91.74	91.77	Tephra	Light gray with dark gray	Fine	Layer	Scoured	Scoured	

Table T5. Glass shard major element composition of tephra in cores, Holes 1150A and 1151C.

Core, section, interval (cm)	Depth (mbsf)	Major element oxide (wt%)										
		SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	*N*	Total
186-1150A-												
1H-4, 54–56	5.04–5.06	76.42	0.37	13.25	1.92	0.09	0.49	2.29	4.03	1.14	14	97.95
		2.1	0.1	0.7	0.6	0.0	0.2	0.5	0.1	0.1		1.9
2H-5, 136–138	15.06–15.08	78.11	0.15	12.50	1.39	0.06	0.16	1.44	3.65	2.53	13	97.50
		0.3	0.0	0.2	0.1	0.0	0.0	0.0	0.2	0.1		1.5
3H-3, 148–150	21.68–21.70	78.96	0.18	12.28	1.31	0.05	0.22	1.50	3.73	1.78	18	95.55
		0.3	0.0	0.1	0.1	0.0	0.0	0.1	0.2	0.1		1.4
3H-5, 71–73	23.91–23.93	75.93	0.40	12.70	2.67	0.10	0.45	2.43	3.56	1.77	18	98.71
		2.2	0.2	0.5	0.9	0.0	0.2	0.5	0.3	0.8		1.4
3H-CC, 22–25	27.27–27.30	72.00	0.41	15.04	1.54	0.10	0.39	1.21	4.45	4.86	20	98.92
		0.6	0.1	0.3	0.2	0.0	0.1	0.2	0.2	0.3		1.5
(1)		72.44	0.39	14.81	1.43	0.08	0.34	1.05	4.42	5.03	12	98.90
(2)		71.33	0.44	15.37	1.71	0.13	0.48	1.45	4.50	4.60	8	98.95
4H-1, 10–12	26.80–26.82	71.78	0.42	15.12	1.60	0.10	0.41	1.30	4.43	4.83	19	99.15
		0.7	0.1	0.3	0.2	0.0	0.1	0.2	0.1	0.2		1.4
(1)		72.48	0.39	14.76	1.46	0.10	0.33	1.03	4.41	5.03	8	98.79
		0.3	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1		1.4
(2)		71.27	0.45	15.38	1.71	0.11	0.47	1.49	4.44	4.68	11	99.42
186-1151C-												
1H-1, 110–112	1.1–1.12	76.62	0.36	13.15	1.87	0.09	0.48	2.28	3.92	1.24	14	98.60
		1.6	0.1	0.6	0.4	0.0	0.1	0.4	0.1	0.1		0.9

Note: *N* = number of analyses.

Table T6. Glass shard major element composition of marker tephra erupted from volcanoes in the Tohoku, Hokkaido, and other distal districts.

Tephra name	Sampling site	Major element oxide (wt%)										
		SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	*N*	Total
Towada-Hachinohe	Tohoku	76.61	0.44	12.83	1.86	0.10	0.66	2.44	4.02	1.05	15	98.23
To-H	Shingo Village	0.52	0.05	0.34	0.16	0.05	0.04	0.14	0.09	0.04		1.49
Narugo-Yanagisawa	Tohoku	79.67	0.16	11.94	1.30	0.06	0.17	1.31	3.62	1.78	40	96.64
Nr-Y	Iwadeyama-cyo	0.3	0.0	0.2	0.1	0.0	0.0	0.1	0.1	0.1		1.4
Shikotsu Daiichi	Hokkaido	77.99	0.15	12.53	1.47	0.08	0.13	1.30	3.78	2.58	23	93.03
Spfa-1	Kamisarabetsu	0.5	0.0	0.2	0.1	0.0	0.0	0.0	0.2	0.1		1.4
Aso-4	Kyusho	73.23	0.40	14.57	1.56	0.09	0.30	1.03	4.23	4.58	26	96.91
	Uenohara-cyo	0.9	0.1	0.5	0.2	0.0	0.1	0.2	0.2	0.3		1.9

Notes: *N* = number of glass shards analyzed by electron probe microanalysis. Quoted from Aoki and Arai, 2000.

Table T7. Similarity coefficient between marine tephras and their correlatives.

Core, section, interval (cm):	1150A-1H-4 54–56	1150A-2H-5 136–138	1150A-3H-3 148–150	1150A-4H-1 10–12	1151C-1H-1 110–112
To-H	0.94	0.70	0.73	0.78	0.93
Spfa-1	0.64	0.94	0.85	0.67	0.65
Nr-Y	0.67	0.89	0.94	0.67	0.69
Aso-4	0.76	0.70	0.69	0.93	0.75

Table T8. Petrographic description of tephra layers in cores, Holes 1150A and 1151C.

Core, section, interval (cm)	Depth (mbsf)	Heavy mineral assemblage	Glass shard type (max. diameter)
186-1150A-			
1H-4, 54–56	5.04–5.06	Opx, cpx, ho	Pm, bw, pumice (23 mm)
2H-5, 136–138	15.06–15.08	Opx, cpx	Pm, bw
3H-3, 148–150	21.68–21.70	Opx, cpx	Pm, bw
3H-5, 71–73	23.91–23.93	Opx, cpx	Pm, bw
3H-CC, 22–25	27.27–27.30	Opx, cpx, ho	Bw, (bw*, pm)
4H-1, 10–12	26.80–26.82	Opx, cpx, ho	Bw, (bw*, pm)
186-1151C-			
1H-1, 110–112	1.1–1.12	Opx, cpx, ho	Pm, bw, pumice (2~3 mm)

Notes: Opx = orthopyroxene, cpx = clinopyroxene, ho = hornblende, bi = biotite, qt = quartz. Bw = bubble-wall type of volcanic glass shards, pm = pumice type of glass shards, fb = P fiber type of glass shards. * = colored glass shards.