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8. HOLE-TO-HOLE CORRELATION OF EOCENE VOLCANIC ASH LAYERS FROM THE BLAKE NOSE DEPTH TRANSECT, LEG 171B[1]

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ABSTRACT

More than 50 discrete volcanic ash layers were recovered at the five drill sites of the Blake Nose depth transect (Leg 171B, western central Atlantic). The majority of these ash layers are intercalated with Eocene hemipelagic sediments with a pronounced frequency maximum in the upper Eocene. Several ash layers appear to be deposited from volcanic fallout with little or no indication of secondary remobilization. They provide excellent stratigraphic markers for a correlation of the Leg 171B drill sites. Other ash layers were probably redeposited from volcaniclastic-rich turbidity currents, but they still represent geologically instantaneous events that can be used in stratigraphic correlation between adjacent drill holes. Additional nonvolcanic marker beds, like the suspect late Eocene impact event layer, were included in our hole-to-hole correlations.

Stratigraphic and downcore positions of marker beds were compiled and plotted against existing composite depth records that were constructed to guide high-resolution sampling. Comparison of our correlation with the spliced composite sections of each drill site reveals several minor and some major discrepancies. These may result from drilling distortion or missing sections, from the lack of unambiguous criteria for the synchronism of ash layers, or from the systematic exclusion of marker-bed data in the construction of the spliced record. Integration of both correlation approaches will help eliminate most of the observed discrepancies.

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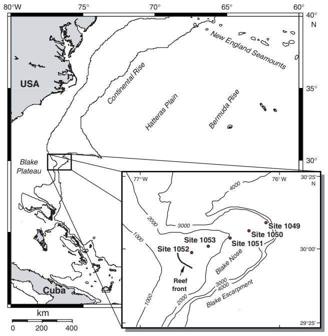
INTRODUCTION

One of the major objectives of Ocean Drilling Program (ODP) Leg 171B was to enable high-resolution studies of the evolutionary, paleoclimatic, and paleoceanographic changes during the early Paleogene. A paleodepth transect along the crest of Blake Nose, a spur of the Blake Plateau that projects into the western central Atlantic, was chosen for this purpose (Norris, Kroon, Klaus, et al., 1998) (Fig. F1). A total of 16 holes was drilled at five sites at present water depths ranging from 1300 to 2700 m. This segment of the continental margin is tectonically undisturbed, and the targeted Paleocene–Eocene sections were not buried to the extent that critical investigations are compromised by diagenetic alteration. A significant part of the recovered Paleocene–Eocene core material was deposited at rates that allow studies to be conducted at high resolution. The integration of all available kinds of stratigraphies and a precise correlation, both between closely adjacent drill holes at one site and across the more distant drill sites of the Leg 171B depth transect, was deemed to be of crucial importance to a successful reconstruction of early Paleogene paleoenvironmental change (Norris, Kroon, Klaus, et al., 1998). In this respect, the recovery of more than 50 discrete volcanic ash layers, most of which occur in hemipelagic sediments of Eocene age, was among the fortunate though unexpected results of Leg 171B. The ash layers and other event beds may provide an elegant tool to complement high-resolution bio-, magneto-, and cyclostratigraphies in the correlation of both drill holes and drill sites. However, a preliminary correlation of ash layers from Site 1051 revealed a number of significant discrepancies in an existing informal composite depth scale (Reicherter and Pletsch, 1998). Since the mismatches appear to result in part from problems with the spliced composite depth section, they may affect high-resolution sampling and need clarification.

F1. Leg 171B drill sites, p. 9.



Herein we present a revised correlation of Eocene marker beds, including the ash layers between individual holes of Leg 171B drill sites with a focus on the apparent mismatches. A correlation of ash layers across the Blake Nose depth transect and a regional study of their dispersal and provenance will be published elsewhere.

MATERIALS AND METHODS

Samples of suspect volcanic ash layers were taken aboard the JOIDES Resolution and at the Bremen Core Repository after description of the sedimentologic characteristics in both the working and the archive halves of the split core sections. Sample splits were then prepared for smear slide, X-ray diffraction, X-ray fluorescence, and scanning electron microscopic analyses (Reicherter and Pletsch, 1998).

The majority of the studied ash layers are intercalated with otherwise relatively monotonous sediments of Eocene age at Sites 1049–1053. Background sediments are yellowish to greenish calcareous oozes, chalks, and marls with variable proportions of calcareous nannofossils and foraminifers and with a significant percentage of siliceous microfossils (radiolarians, sponge spicules, minor diatoms). Clay content generally increases downcore, and there are occasional intercalations of porcellanite and chert (Norris, Kroon, Klaus, et al., 1998). A few more indistinct ash beds and smectite-rich bentonites were detected in Paleocene and Upper Cretaceous marlstones, but those will not be discussed here. The Eocene ash layers, which range in thickness from a few millimeters to more than 5 cm are composed of largely unaltered volcanic glass, occasional biotite, and rare feldspar, including sanidine. The dacitic-rhyodacitic composition of most ash layers suggests a provenance from a calc-alkaline volcanic source in the Caribbean Island arc (Reicherter and Pletsch, 1998).

Several ash layers are strongly diluted with the biogenic background material. Notably, well-preserved radiolarian tests occasionally constitute >50% of the sediment. These ash layers are often strongly bioturbated and show indistinct bedding contacts, which suggest direct settling of air-fall deposits through the water column (Reicherter and Pletsch, 1998). Other ash layers display distinct normal grading with sharp basal contacts to the background sediment and only minor signs of benthic remobilization. The ratio of volcanic particles vs. biogenic components in these beds decreases with decreasing grain size, the <63-µm fraction being usually glass dominated. These layers were interpreted as volcaniclastic turbidite deposits (Reicherter and Pletsch, 1998). Although these strata obviously represent geologically instantaneous events that are useful in the correlation of closely adjacent drill holes, care must be taken when correlating the turbidite ash layers across the depth transect since the transporting turbidity currents may have reworked older ash layers upslope from the depositional site.

The procedure for ash correlation consisted in discriminating which of the suspect ash layers truly consists of at least common volcanogenic particles. Inspection of smear slides revealed a significant number of "pseudo-ash layers" where the conspicuous dark color results from phosphatic components, glauconite, mass accumulations of siliceous microfossils, or clay enrichments. Although these layers are not volcanogenic, some of them also represent geologically instantaneous events and thus provide useful stratigraphic markers. The marker beds (ash layers and miscellaneous event strata) were consecutively labeled downcore with a letter code, with the intention to apply the same letters to correlative layers between the drill holes of one site but without any implication of correlation across sites.

The depths in meters below seafloor (mbsf) of the remaining marker beds were then corrected with the offsets provided by the shipboard core-core integration and entered into a spliced section with a composite depth scale in meters composite depth (mcd). Details of the splicing procedure are given in Hagelberg et al. (1992, 1995) and Norris, Kroon, Klaus, et al. (1998). The informal Leg 171B composite depth section was constructed on the basis of densely spaced physical property measurements (multisensor track magnetic susceptibility, gamma-ray attenuation porosity evaluator [GRAPE] density, color reflectance) by assigning a linear depth offset to each core from a multiple-hole setting. Although this can be conveniently performed on board using a special software package, it is difficult to line up all prominent measurement features in two cores by a single linear depth shift.

In spite of the sophisticated splicing technique, we found a number of major discrepancies between the spliced record and our correlation (Table T1). Where discrepancies occurred, we reexamined the smear slides and core photographs to decide whether or not the correlation of our event layers was conclusive. This was not an easy task in cases where several ash layers occur over a short interval or where layers are missing due to coring gaps, but we are confident about the correlation of marker beds presented here (Table T1). Even where the marker beds were perfectly lined up on the mcd scale, we had to use additional arguments to avoid circular reasoning, because the composite depth scale

T1. Correlations between marker beds and drill holes, p. 10.

was then tied to the position of these ash layers. Shipboard biostratigraphic data were used to overcome this dilemma and to substantiate our correlation.

HOLE-TO-HOLE CORRELATION

Site 1049

Correlation at Site 1049 was problematic because of a misestimation of the seafloor depth in Hole 1049A on the order of 15 m, to spot coring in Holes 1049B and 1049C, and to a generally incomplete recovery of the Eocene sections as a result of intercalated chert layers (Norris et al., 1998). This may explain the 2.34-m mismatch on the composite depth scale of marker bed 49A, a vitric ash layer with biotite flakes that was identified in Holes 1049A and 1049B (Table T1). Two other pairs of marker beds, lower in the section, show a lesser offset on the mcd scale and together provide a cross-correlation of the three holes drilled at Site 1049.

Site 1050

The first two pairs of marker beds at Site 1050 show an almost exact match on the composite depth scale (50A and 50B; Table T1). The perfect coincidence is a result of the pronounced spikes in magnetic susceptibility of these ash layers that were used in the construction of the spliced record (Norris et al., 1998). Other parts of the section, however, show significant mismatches between correlative ash layers of the two holes which amount to >3 m. Even close inspection of the intervals 5 m above ash layers 171B-1050A-11X-5 (15–16 cm), 14X-4 (139–140 cm), and 21X-1 (59–60 cm) and 5 m below ash layers 171B-1050B-11X-6 (27–28 cm), 14X-5 (48–49 cm), and 22X-2 (133–134 cm), respectively, revealed no other ash layers that may have been overlooked during shipboard description. Since the three ash layers in Hole 1050A are offset in the same direction, we suspect a systematic error in the spliced record in the intervals between 100 and 135 mcd and around 190 mcd. Except for the lowermost marker bed, these cores are from intervals where recovery was notoriously incomplete and where adjustments to the composite section were admitted to be weakly justified (Norris, Kroon, Klaus, et al., 1998). Drilling of these cores with the extended core barrel (XCB) has pervasively disturbed the sediment around intact drilling biscuits. As a result, one or more ash layers may have been missed, and we cannot be absolutely confident about our correlations, either. Strikingly, another good match was obtained for marker bed 50G, an altered ash layer with an eroded hardground at the top, between the two intervals that show significant discrepancies.

Site 1051

The most expanded Eocene section and the largest number of ash layers were recovered at Site 1051. Recovery in the upper 150 mbsf was excellent and dropped only slightly in the chalk section down to about 300 mbsf of both holes where XCB drilling was used (Norris, Kroon, Klaus, et al., 1998). Correlation of ash layers throughout this interval is good with discrepancies being generally <1 m (Table T1). Particularly clear examples of correlative ash beds in this interval are marker beds

51I and 51J, which were shown to have the same thicknesses, size-grading and bioturbation patterns, and compositions (Reicherter and Pletsch [1998], pl. 1). In another occasion, exact correlation appears obvious from the close and constant distances (1.41 and 1.39 m) between marker beds 51N and 51O. The 2.8-m discrepancies in their positions on the mcd scale must result from the choice of rather noisy color and weak magnetic susceptibility data. Surprisingly, neither pair of ash layers was used as a tie point in the construction of the composite splice. Between 370 and 400 mbsf, several intercalations of chert and limestone led to extremely poor recovery (Norris, Kroon, Klaus, et al., 1998). In spite of these difficulties, the ash correlations show only minor offsets on the mcd scale.

Site 1052

Part of the upper Eocene was cored in five holes at Site 1052 that share two ash marker beds, 52B and 52C (Table T1). As in the previous holes, these ash layers were not used for the core-core integration, in spite of their recognition in the GRAPE density record (density minima d and e–f, respectively; Norris, Kroon, Klaus, et al., 1998). This partially explains the minor discrepancies when the ash layers are plotted on the mcd scale. In addition to this source of mismatch, the uppermost cores are characterized by variable overlap or missing section at the core breaks, as suggested by substantial differences in the distance between the two marker beds in any one drill hole. Throughout the rest of the section, the mcd discrepancies between marker beds are fair to good.

Site 1053

Only three out of eight marker beds at this site were found to correlate across the two holes (Table T1). Among these, marker bed 53D is a prominent example of a nonvolcanic event bed. In both holes, the respective intervals (171B-1053A-8H-2, 76–84 cm, and 171B-1053B-8H-5, 50–57 cm) consist of dark grey diatomaceous clay with sharp lower contacts and gradational and bioturbated tops. At least 20 species of diatoms are present in these beds, whereas diatoms are not abundant or diverse above and below (Norris, Kroon, Klaus, et al., 1998). Nickel-rich spinels attributed to the elusive late Eocene impact event at 35 Ma were found in one of these beds in Hole 1053B (J. Smit, pers. comm., 1999). No similar beds were observed throughout the rest of the section; obviously, they provide a perfect correlation marker. Yet the spliced record makes no use of this horizon, in fact, it shows the largest apparent offset (2.76 m) on the composite depth scale at Site 1053.

DISCUSSION

High-resolution studies of sedimentary sections from multiple drill holes must rely on composite depth sections which are constructed so as to avoid overlaps or missing sections that are inherent with drilling processes. The erection of such a composite section involves depth shifting and splicing of selected intervals that are tied to each other at correlative features (Norris, Kroon, Klaus, et al., 1998). Physical properties measurements have proven to be very successful in the construction of spliced composite records, mainly because they can be obtained in a quasi-continuous fashion through automated measurements. The rapid availability of these data on board and the relative ease with which these records can be assembled to a composite section have led to their increasingly wide application in high-resolution studies (Hagelberg et al., 1992, 1995). However, where a large part of the basic data sets are weak and noisy, as in the case of the Leg 171B drill holes, the splicing procedure is prone to correlation artifacts. This is expressly stated in the respective site chapters of the Initial Reports Volume 171B (Norris, Kroon, Klaus, et al., 1998). Once more obvious tie points are available, we should reevaluate the preliminary spliced record and rescale the composite depth section to line up the least ambiguous stratigraphic markers.

The accumulations of volcanic ash layers at the Leg 171B drill sites, either by direct settling of airborne ash or by deposition from turbidity currents, are geologically instantaneous events. The same applies to the diatomite mass occurrence that potentially represents the late Eocene impact event at Site 1053. Given their pronounced differences in lithofacies and other physical properties from the background sediments, these event layers can be conveniently used as marker beds for correlation purposes. The use of unique marker beds as correlation tie points is intuitively more satisfying than the application of physical properties data of variable quality, in spite of the admittedly much denser spacing of the latter (Norris, Kroon, Klaus, et al., 1998).

Since the composite depth scale was not routinely rescaled to the positions of marker beds, we expected some discrepancies to occur between the spliced record and our correlation. Among the reasons for these discrepancies are coring-related problems which apply to both the ash correlation and the splicing procedure. These include incomplete or duplicate recovery, as well as the more tricky differential decompaction of the cored sediments. Another cause of apparent offsets is the occasional lack of unequivocal criteria for the recognition of correlative features, which again applies to both approaches.

However, the magnitude and the abundance of apparent mismatches of marker beds, like those of the clearly correlative turbidite ash layers at Site 1051 and the diatomaceous clays at Site 1053, are so large that we suspect a systematic problem with the splicing procedure. The most important source of mismatch is the deliberate exclusion of supposedly erratic peaks from the splicing procedure (Norris, Kroon, Klaus, et al., 1998). Exclusion of “anomalous” readings is certainly appropriate when there is no control about their correlation between the holes, as in the case of diagenetic nodules, downcore contamination, or in other cases of inhomogeneous lithologies. Even in those instances where an exact match between ash layers or other marker beds was achieved, additional arguments have to be used to substantiate correlations because this usually means that the composite depth scale is then tied to the position of these ash layers. We can use biostratigraphic and magnetostratigraphic data to avoid this type of circular reasoning.

High-resolution records or calculations of sedimentation rates for the intervals where we found major discrepancies between the ash correlation and the spliced record are likely to be erroneous; sampling strategies for these intervals must consider the potential of missing or duplicated sections. Whatever the ultimate reason for the observed discrepancies, an attempt should be made to integrate both correlation approaches to arrive at a more robust composite depth section of the Leg 171B drill sites. To avoid confusion, we made no effort to revise the existing composite depth scale at this stage, since our correlation still awaits confirmation from the petrographic and geochemical analyses mentioned above.

CONCLUSIONS

The unexpected find of >60 discrete Paleocene to Eocene volcanic ash and other event layers, in conjunction with a high-resolution bio-, magneto-, and cyclostratigraphy, provides potential for a very detailed integrated stratigraphic correlation of the Leg 171B drill sites. In the course of our study, we found that some of the ash layers initially described on board do not contain any appreciable volcanogenic material, whereas other ash layers were not previously detected.

The correlation presented here has given rise to concern about the construction of composite depth scales, since there are several significant mismatches of correlative layers. Among other reasons that apply to both the classical visual correlation and the splicing procedure, these discrepancies seem to result mainly from the systematic exclusion of "anomalous" measurements during the splicing procedure. Integration of both correlation approaches—observation of discrete marker beds and the fit of quasi-continuous measurements—may help to eliminate most discrepancies.

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Figure F1. Bathymetric map of the western central Atlantic Ocean. The inset shows Leg 171B drill-site locations on the Blake Nose depth transect.

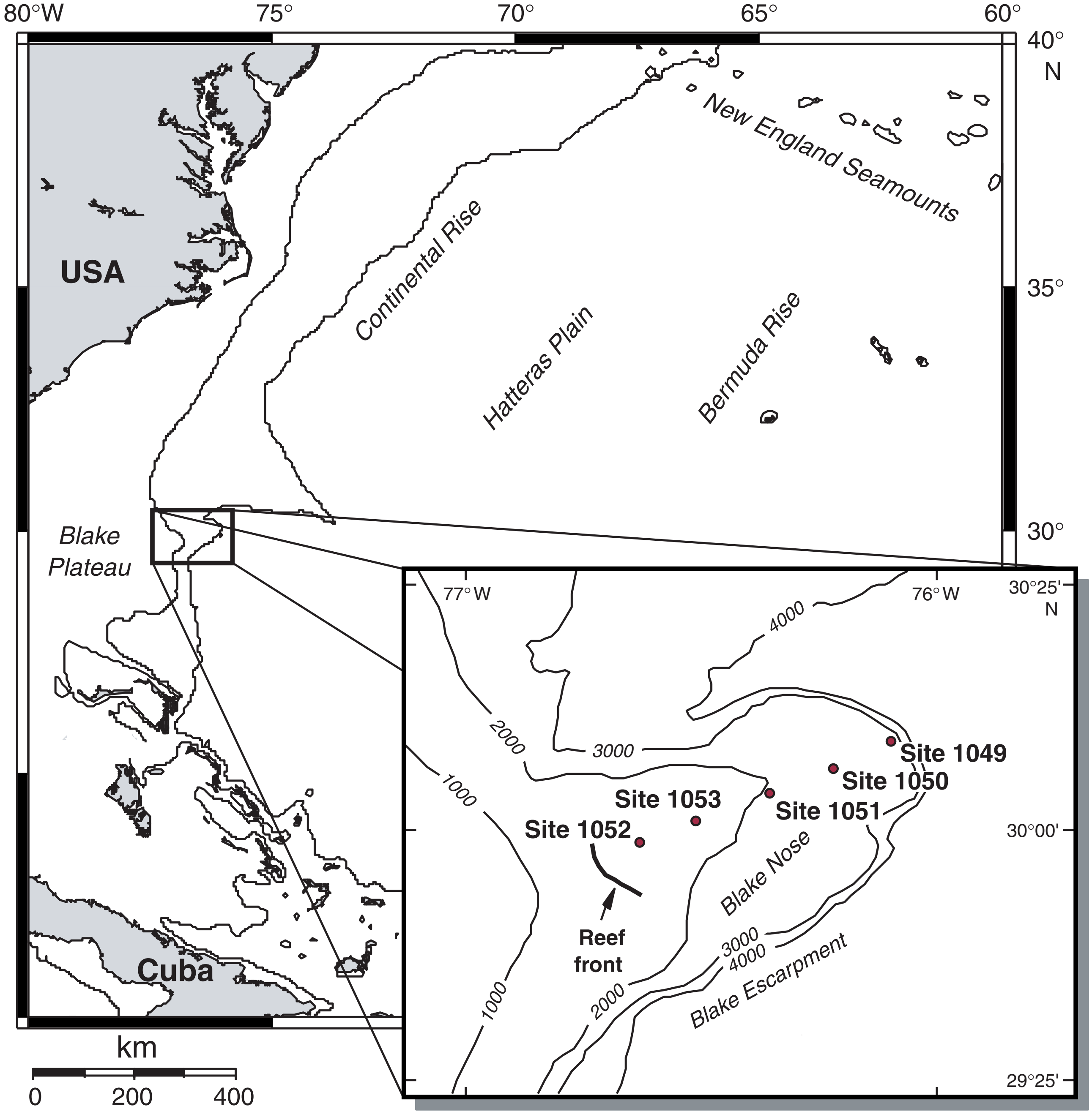

Table T1. Correlations between marker beds and drill holes, Leg 171B.

Code	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Mismatch (mcd)	Remarks
	171B-1049A-			171B-1049B-										
49A	5H-6, 5-6	47.16	33.10	3H-CC, 10-11	30.76	30.76							2.34	Vitric ash
49B	6H-4, 54-58	54.18	40.12	5H-1, 87-90	40.90	40.90	171B-1049C-						0.78	Vitric ash, biotite
49C				5H-4, 73-76	45.26	45.26	5H-4, 25-31	44.81	44.81				0.45	Vitric ash
	171B-1050A-			171B-1050B-										
50A	1X-5, 12-15	6.15	6.99	1X-5, 95-98	6.98	6.98							0.01	Vitric ash, biotite
50B	7H-1, 129-130	58.90	61.31	7H-4, 37-38	59.38	61.32							0.01	Vitric ash, opaques
50D	11X-5, 15-16	101.76	106.32	11X-6, 27-28	98.38	103.12							3.20*	Vitric ash
50F	14X-4, 139-140	130.30	134.66	14X-5, 48-49	125.89	130.63							4.03*	Vitric ash, rare brown glass
50G	16X-7, 42-48	153.08	157.39	17X-6, 24-32	155.52	157.74							0.35	Altered ash, hardground
50K	21X-1, 59-60	190.20	193.91	22X-2, 133-134	189.44	189.05							4.86	Vitric ash, abundant biotite
	171B-1051A-			171B-1051B-										
51E	9H-6, 120-121	81.01	91.37	10H-4, 111-113	86.43	91.94							0.57	Vitric ash
51F	10H-4, 61-62	86.92	97.28	11H-2, 39-41	89.21	97.96							0.68	Vitric ash
51I	20X-7, 34-36	186.76	199.70	21X-6, 3-5	189.25	200.55							0.83	Vitric ash
51J	26X-3, 60-63	238.63	254.58	26X-7, 6-8	238.78	254.67							0.09	Vitric ash
51L	32X-5, 141-143	300.03	319.51	33X-6, 109-111	302.21	318.96							0.55	Vitric ash
51M	33X-1, 132-134	303.54	322.97	34X-2, 138-140	306.10	322.84							0.13	Vitric ash
51N	34X-5, 118-119	318.99	338.42	36X-3, 126-128	317.18	335.61							2.81	Vitric ash
51O	34X-7, 8-10	320.40	339.83	36X-4, 115-117	318.57	337.00							2.83	Vitric ash
51R	41X-1, 75-78	380.08	398.17	43X-1, 10-30	376.40	397.50							0.67	Bentonite, Fe-oxides
51T	43X-1, 132-133	400.83	418.62	47X-3, 95-97	403.27	418.99							0.37	Vitric ash
51U	43X-3, 51-53	403.83	420.82	47X-4, 73-75	404.55	420.27							0.55	Vitric ash, biotite
	171B-1052B-			171B-1052C-			171B-1052D-			171B-1052F-				
52B	2H-3, 88-91	8.91	10.99	1H-7, 19-20	9.20	10.96	2H-3, 117-118	13.68	10.66	2H-2, 20-25	11.25	10.90	0.33	Vitric ash, biotite
52C	2H-5, 63-68	11.68	13.76	2H-1, 84-90	10.40	13.01				2H-4, 13-16	14.16	13.82	0.81	Vitric ash
	171B-1052A-			171B-1052B-			171B-1052F-							
52D	3H-3, 78-80	19.82	23.06	3H-4, 90-95	19.95	23.19	3H-3, 65-70	22.70	23.40				0.34	Vitric ash
52E	3H-CC, 5-7	22.63	26.03	3H-7, 25-27	23.77	27.01							0.98	Vitric ash
52F	4H-5, 6-8	28.78	30.61	4H-3, 87-88	27.88	30.46	4H-1, 124-125	29.75	30.46				0.15	Vitric ash
52G	5H-5, 59-61	38.81	42.14	5H-4, 115-120	39.24	42.21	5H-3, 69-73	41.73	43.65				1.51	Vitric ash
52H	6H-6, 62-63	49.83	55.75	6H	47.95-51.80**	52.80-56.70**	6H-5, 10-11	53.61	56.08				0.95†	Vitric ash, biotite
52I	8H-5, 96-97	67.67	71.44	9H-3, 109-110	66.60	71.69	8H-3, 82-85	70.35	71.70				0.26	Vitric ash
52J				9H-5, 87-88	69.38	74.47	8H-5, 77-78	73.28	74.63				0.16	Vitric ash
52K	10H-4, 70-71	84.91	88.93	11H-2, 33-34	83.34	88.96	10H-5, 18-20	87.20	88.96				0.03	Vitric ash
52L	11H-5, 106-108	96.28	101.46	12H-3, 72-75	94.75	101.45	11H-6, 92-101	99.01	101.49				0.04	Vitric ash, brown glass
	171B-1053A-			171B-1053B-										
53B	1H-2, 99-102	2.52	2.72	1H-2, 122-123	2.73	2.73							0.01	Vitric ash
53D	8H-2, 76-84	68.84	69.19	8H-5, 50-57	67.47	71.95							2.76	Diatomite, rare glass
53F	9H-6, 121-122	84.72	87.94	10H-3, 42-45	83.35	87.81							0.13	Vitric ash, clear

Notes: * = correlation is uncertain because of drilling disturbance. ** = sampling interval is not labeled clearly. Values indicate maximum depth ranges. † = minimum value.