36. COMPOSITION, K–Ar DATES AND ORIGIN OF A MID-EOCENE RHYOLITIC ASH LAYER AT DEEP SEA DRILLING PROJECT SITES 605 AND 613, NEW JERSEY TRANSECT, LEGS 93 AND 95[1]

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ABSTRACT

A 2–5-cm-thick, middle to lower middle Eocene, vitreous ash layer of rhyolitic composition can be correlated between Sites 605 and 613 on the uppermost continental rise off New Jersey. The ash is tentatively interpreted as a wind-transported submarine fallout tephra from a major subaerial eruption of the Bermuda volcano, shortly after its emergence above sea level. The K–Ar dates of 45 Ma for a coarse size fraction of the two ashes and 40 Ma for a fine fraction of one of the samples are discordant and are only in rough agreement with the biostratigraphic age.

INTRODUCTION

Ash layers are very rare in the Cretaceous and Tertiary sediments of the eastern North American continental margin. Today, the volcanic centers of the Bermuda Islands to the southeast and of the Caribbean area to the south are about 1000 and 2000 km away (Fig. 1). To our knowledge, no distinct ash layers were reported from the Eocene sections of other DSDP sites between the New Jersey continental margin and Bermuda. (e.g., Sites 386, 387, 8, 108, 612) or from the COST B-2 and COST B-3 wells, in which mid-Eocene sediments were also penetrated (Tucholke, 1979; Scholle, 1977, 1980). Therefore, the vitreous ash layer in Samples 605-21-2, 145–147 cm and 613-34-1, 104–109 cm, from two sites which are located only 8 km apart on the uppermost continental rise off New Jersey, form an important marker horizon which interrupts the monotonous, hemipelagic, calcareous sedimentation. This ash layer helps to correlate both sites, calibrates the biostratigraphic age data, and allows us to draw some inferences about the structural and volcanic evolution of the distant Bermuda archipelago.

METHODS

We investigated the composition and texture of the ash layers by smear slides (Table 1), grain mounts, and thin sections (Fig. 2). The samples were sieved into subsamples of <32 and >32 (32–250) μm; however, the <32 μm fraction of the Site 605 sample was too small for analyses. For the isotope and chemical analyses the vitreous glass was concentrated by decalcification (formic acid) and for the Site 605 sample, in addition, by heavy liquids to separate pyrite (and glauconite) from the lighter-weight glass. The two size fractions of the Site 613 sample were analyzed for major and trace elements by X-ray fluorescence (XRF) (see Table 2). Conventional total-fusion, mass-spectrometric, isotope-dilution argon analyses and flame-photometric potassium analyses were performed on the single size fraction of the Site 605 sample and the two size fractions of the Site 613 sample (Table 3). Brief analytical details are given by Seidel et al. (1982), and results for standard minerals are in the interlaboratory compilation of Odin (1982a).

PETROGRAPHY AND GEOCHEMISTRY

The ash layer at Site 605 is 2–3 cm thick; the layer at Site 613 is 5 cm thick. Petrographically, both layers are similar, and their volcanic constituents appear to be identical. The layers consist mostly of comparatively fresh, transparent, light-colored, highly vesicular pumice fragments and about 30% bubble-wall shards, mostly less than 40 μm in diameter (Fig. 2; Table 1) with a maximum size of 150 μm. Their refractive index is n = 1.495–1.500. The ash layer at Site 605 contains much secondary pyrite, some quartz, feldspar, "clay"/leucoxene aggregates (probably altered glass), biogenic carbonate, and traces of glauconite. The ash layer at Site 613 contains only very little quartz, feldspar, pyrite, biotite, "clay" aggregates, and no carbonate.

A high concentration of ~99% glass was achieved in the <32 μm fraction of the ash from Site 613. For this fraction, as well as for the >32 μm fraction, which is less representative for the glass alone, the calculation of the volcanic norm (Müller, 1982) from the chemical composition (Table 2) points to a rhyolitic volcanic source. Compared with this composition, the refractive index of 1.495 to 1.500 seems to be reduced and is representative for (rhyolite to) pitchstone (Tröger, 1971; Huber and Rinehart, 1966), well in agreement with the patchy birefringence and the high loss on ignition (LOI) of 9.9 and 13.0 wt.%, respectively (three to ten times higher than for unaltered glass) that these samples display.

DISCUSSION OF K–Ar DATES

The K–Ar dates determined for the >32 μm fractions of both ash layers are the same: 44.5 ± 1.2 Ma for Site 605, and 44.8 ± 0.9 Ma for Site 613. In contrast, the K–Ar date determined for the <32 μm fraction of the ash layer from Site 613 is significantly younger, 39.9 ± 0.7 Ma (Table 3). In this chapter we offer only tentative interpretations of these data.

We suggest that the ash layer represents an airborne ash from a subaerial oceanic environment. If this is so,

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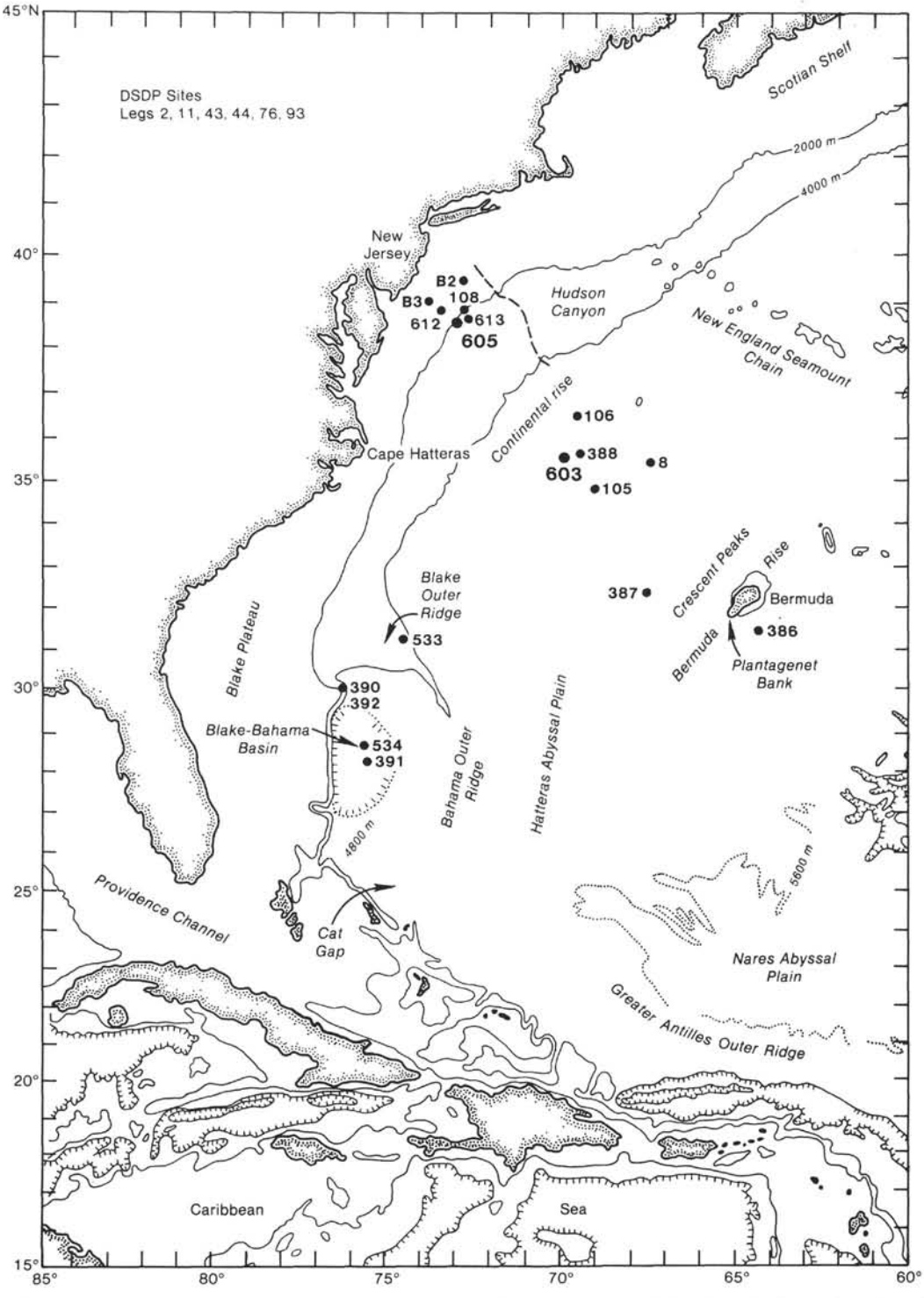

Figure 1. Location map of DSDP sites and of COST-B wells in the eastern North American Basin, and location of the potential source areas of the ash (Bermuda Islands, Caribbean).

the dates are not likely to be significantly too old from excess argon. Nor does an inherited component seem to be a problem, because the >32 μm fraction of the Site 613 sample, although contaminated with a trace of biotite, yielded the same date as the same fraction of the biotite-free Site 605 sample. However, the high LOI and the patchy birefringence of the glass show that it is altered. In general, any visible alteration of glass is accompanied by loss of radiogenic argon, leading to K–Ar dates that are too young. From these arguments, we suggest that the three dates are minimum estimates of the age of eruption of the ashes and explain the significantly younger date by a large loss of radiogenic argon in the fine size fraction.

Table 1. Geographic, biostratigraphic, and petrographic data for the ash layers.

	605-21-2, 145–147 cm	613-34-1, 104–106 cm
Coordinates	38°44.5'N, 72°36.6'W	38°46.3'N, 72°1.4'W
Water depth (m)	2194	2309
Depth in hole (m)	340	403
Nannoplankton Zone	CP13	CP13a
Petrography	Vitreous siliceous ash layer, rhyolitic, 2–3 cm thick	Vitreous siliceous ash layer, rhyolitic, 5 cm thick
Mineral composition of the entire ash		
Size fraction >32 μm	Glass, mod. altered, much pyrite, subord. qtz/feldspar, "clay" aggr., carb., trace of glauconite	Glass, slightly altered, qtz, feldspar, pyrite, biotite, "clay" aggr., radiolarians
Size fraction <32 μm	Not determined	About 99% glass, traces of pyrite, biotite, qtz/feldspar, siliceous org., "clay" aggregates
Refractive index of glass	1.495 to 1.500	1.495 to 1.500

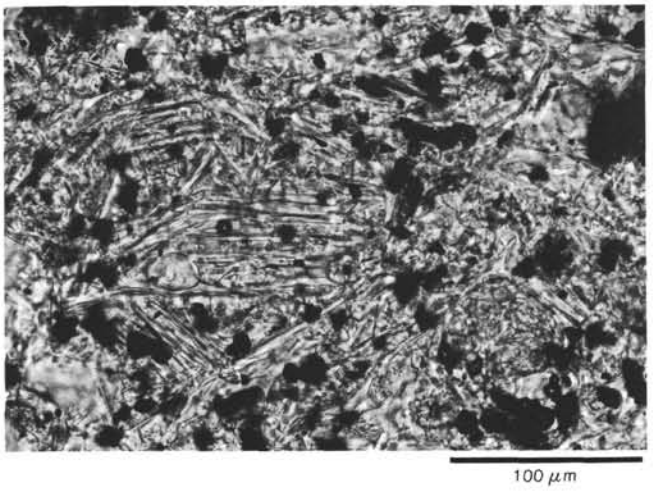

Figure 2. Vitreous ash layer with transparent bubble-wall glass shards, small pyrite spherules, and a few scattered, terrigenous quartz grains. Sample 605-21-2, 145–147 cm.

Biostratigraphic information from foraminifers, radiolarians, and nannofossils from the overlying and underlying silica-rich nannofossil chalk dates the ash layers at Sites 605 and 613 as nannoplankton Subzone CP13a (Poag, Watts, et al., in press). According to the correlation table of Bukry (1981, fig. 2), dates correspond to the early to the middle part of the middle Eocene (calcareous nannoplankton Zone NP15/lower part of NP16) and the early part of the middle Eocene (basal nannoplankton Zone NP15/NP16), respectively (Fig. 3).

In contrast, the timescales of Curry and Odin (1982) and Odin (1982b) suggest that basal NP15/NP16 correlates with a middle middle Eocene age of around 42 to 41 Ma. By this time scale, our "minimum age" of 45 Ma for the basal NP15/NP16 of the ash layer at Sites 605 and 613 seems to be too old. Either our assumptions about the origin of the ash are incorrect, or the dates are in accordance with the competing time scales

Table 2. X-ray fluorescence analyses[a] of the two size fractions from the ash layer in Sample 613-34-2, 104–106 cm.

Elements	Fraction >32 μm	Fraction <32 μm
Major elements (wt.%)		
SiO_2	52.4	62.4
TiO_2	0.2	0.3
Al_2O_3	10.5	12.7
Fe_2O_3	15.5	6.2
MnO	0.03	0.03
MgO	0.4	0.7
CaO	1.8	1.2
Na_2O	2.1	2.6
K_2O	2.9	3.3
P_2O_5	0.06	0.1
SO_3	0.7	0.1
LOI	13.0	9.9
Total	99.6	99.5
Trace element (ppm)		
Ba	401	549
Ce	11	49
Co	17	10
Cr	4	9
La	3	33
Sc	4	1
V	11	15
As	<5	<5
Bi	<6	<6
Cu	76	76
Mo	<3	<3
Nb	8	11
Ni	32	54
Pb	96	69
Rb	74	82
Sn	72	27
Sr	212	233
Ta	16	7
Th	47	24
U	<3	4
W	15	6
Y	<3	<3
Zn	68	33
Zr	153	123
Total (wt.%)	0.1	0.1

[a] Philipps XRF sequence spectrometers PW 1450 (major elements) and PW 1400 (trace elements); matrix correction by interelement Philips alpha-correction factors; air-dry sample material; LOI at 1000°C in air; remainder mixed 1:5 with 1:1 mixture of Li metaborate/tetraborate and fused at 1300°C in a platinum crucible. Analysts: J. Lodziak and D. Requard.

of other authors who regard glauconite dates as minimum estimates of the age of the host sediments, and who used dates of glauconites which Odin considers to be reworked (e.g., Hardenbol and Berggren, 1978). According to these last, the age of basal NP15/16 would be about 49 to 47 Ma (recalculated, see Fig. 3).

ORIGIN OF THE ASH LAYER

Volcaniclastic turbidites and ash layers in marine sediments not only provide valuable, widespread stratigraphic markers (Kennett, 1981), but also permit the assessment of the tectonic and volcanic evolution of a volcanic

Table 3. K-Ar data[a] for the ash layer at Site 605 (Leg 93) and 613 (Leg 95).

Size fraction, pretreatments, composition	K (wt.%)	Argon		K-Ar date (Ma)
		Atmospheric (nl/g) STP	Radiogenic (nl/g) STP	
Sample 605-21-2, 145-147 cm				
32-250 μm, formic acid, partly 15% HCl, density < 2.8 g/cm^3 predomin. mod. altered glass, subord. fresh glass, qtz/feldspar, "clay" aggr., trace of ore	2.87 2.84 Mean 2.85 ±0.04	4.23 ±0.43	4.99 ±0.12	44.5 ±1.2
Sample 613-34-1, 104-106 cm				
>32 μm, 90% glass, 7% aggregates, 2% pyrite, 1% biotite	2.37 2.39 XRF Mean 2.38 ±0.04	7.28 7.70 7.5 ±0.4	4.18 4.21 4.19 ±0.04	 44.8 ±0.9
<32 μm, 99% glass, traces of pyrite, biotite, quartz, feldspar, and "clay" aggr.	2.69 2.70 XRF Mean 2.70 ±0.04	11.2 10.6 10.9 ±0.7	4.24 4.23 4.23 ±0.04	 39.9 ±0.7

[a] Argon in nanoliters per gram at standard temperature and pressure (nl/g) STP, corrected for the mean of blank analyses. IUGS-recommended constants used (Steiger and Jäger, 1977). Errors estimated at the level of 95% of intralaboratory analytical confidence. Our K-Ar dates of standard minerals are 1% younger than the mean values of an interlaboratory comparison (Odin, 1982a).

archipelago from its submarine seamount to subaerial volcano stage (Schmincke and von Rad, 1979; Fisher and Schmincke, 1984).

Since no volcanic province lies close to Sites 605 and 613, we have to look for more distant source areas. Tentatively, we suggest that the ash layers were derived from a major, explosive, subaerial eruption of the midplate volcanic edifice of Bermuda Island. Site 386, 90 km southeast of Bermuda (Fig. 1), penetrated the entire volcanogenic formation (Vogt and Tucholke, 1979). Volcaniclastic, clinopyroxene-rich turbidites recording the subaerial weathering of Bermuda appear in the upper middle to lower upper Eocene and continue through the upper Oligocene; volcaniclastic debris and scattered ash occur up to the middle Miocene (Galehouse, 1979). The thickest volcaniclastic turbidites were found in Core 386-13 (NP17/18, about 38 to 36 Ma or 42 to 39 Ma, depending on the preferred timescale, see Fig. 3). This suggests that about 50–70 Ma after the formation of the surrounding seafloor at the Bermuda Pedestal "the principal Bermuda volcanoes had been constructed to and above sea level in a main shield-building tholeiitic stage at about 46 Ma B.P. (recalculated according to Steiger and Jäger, 1977)" and that "the volcanoes were largely levelled by erosion in the next 10–20 Ma". Furthermore, "during the erosional period, some ash-producing volcanism may have occurred" (Vogt and Tucholke, 1979, p. 854; Reynolds and Aumento, 1974). Discrete ash layers, recording ash-producing volcanism during the post-early Eocene erosional phase, are absent at DSDP Site 386 on the Bermuda Pedestal and at Site 387 on the Bermuda Rise (Fig. 1). This is surprising in view of the ash layer at Sites 605 and 613, which were at that time about 600 km northwest of Bermuda. Maybe southeasterly high-altitude winds dispersed the fine-grained vesicular ash shards only to the northwest, where the pumice fell into the sea. However, another possibility which cannot be

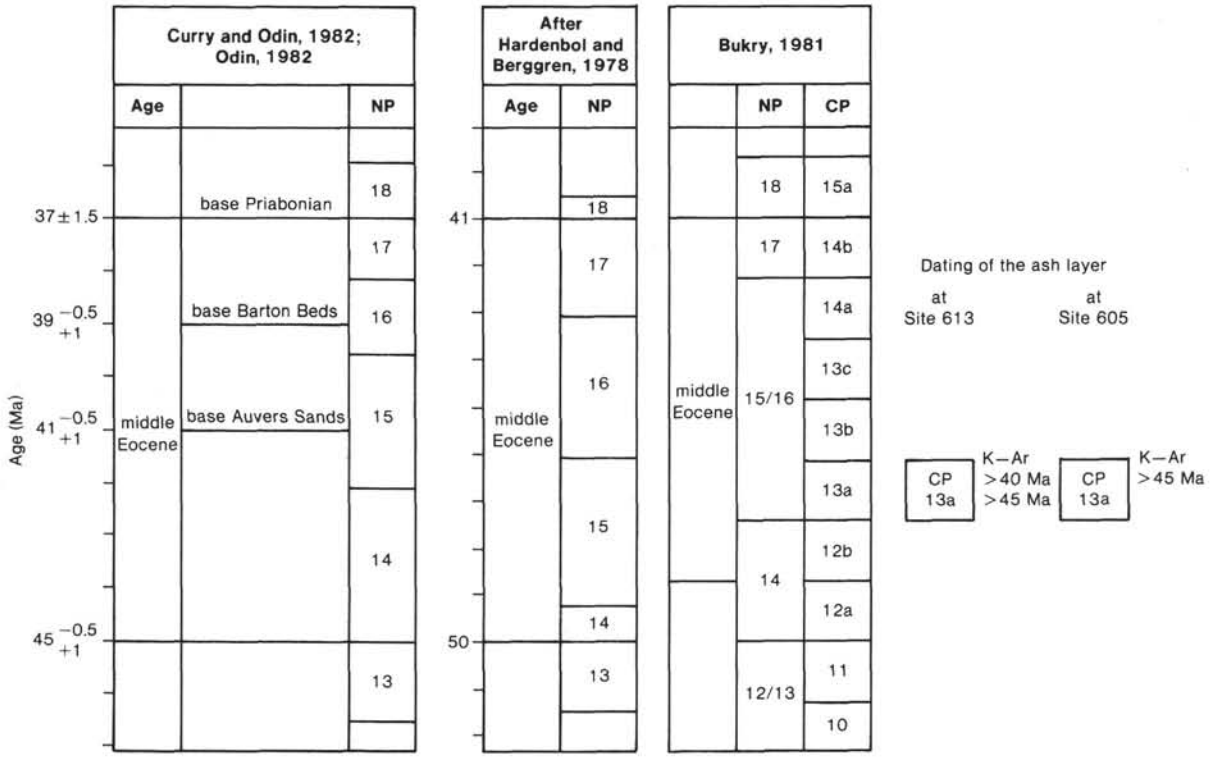

Figure 3. Comparison of different timescales with the age estimates for the ash layers. NP and CP are zonations of calcareous nannoplankton. Arbitrarily, we adjusted the bases of NP18 and NP14 to the same levels. The timescale of Hardenbol and Berggren is increased by 1 Ma to account for the change due to the constants recommended by the International Union of Geological Scientists (Steiger and Jäger, 1977).

ruled out would suggest that the ash layers originated from Caribbean volcanic centers, now >2000 km to the south, which were highly active during the middle Eocene.

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