APPENDIX 3

INTERPRETATION OF THE SOILS AT THE BLUEBERRY HILL ARCHÆOLOGICAL SITE NEAR DOVER, DELAWARE

BY
J. E. FOSS, R. J. LEWIS, AND M. E. TIMPSON

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INTRODUCTION

This soils study is concerned with Blueberry Hill, site 7K-C-107, located on the west bank of Fork Branch in the city limits of Dover, Delaware. The site is situated on a sand dune that has apparently been preserved from large-scale disruption; surrounding areas show ample evidence of the construction of the railroad, recreational activities, and other functions that could cause instability and erosion.

Sand dunes are quite common in Delmarva and provide many of the "hills" that are noted on some landscapes. Sand dunes have been described by Denny and Owens (1979) in Maryland and Delaware; they placed a date of 30,000 to 13,000 years B.P., although they did suggest that some of the dunes may be Holocene. Other evidence of wind activity in Maryland during the late Pleistocene or early Holocene is suggested by the carbon-14 date of 10,520 years B.P. under loess near the Chesapeake Bay (Foss 1978). Studies by Owens et al. (1974) have suggested that the bulk of estuarine deposition began in Chesapeake Bay region around 11,000 years ago. The basis for this are carbon-14 dates on peat or wood from the base of the estuarine sediments of 15280 and 10,340 years B. P. by Harrison et al.(1965) and a date by Owens et al. (1974) of 9,800 years B.P. Undoubtedly, wind erosion and deposition continued into the Holocene, especially during drought or instability periods. Wind erosion is a common phenomenon in Delmarva today during the spring or during dry periods.

The objectives of the soils study were to (a) describe the morphology of the major soils at Blueberry Hill, (b) determine the physical and chemical properties of the soils, and (c) help the research team reconstruct the Holocene environment based on not only soils information but also archæological, geological, and other data.

METHODS

The soils were described and sampled in archæological excavations, and in some cases an auger was used to examine the sediments to depths of two meters or more. Descriptions were made according to methods developed by USDA, Soil Conservation Service.

Particle size analysis was accomplished by sieving the sample through a 10-mesh sieve (2 mm openings), and then using the soil that passed through the screen for further analysis. Sand separations were made by sieving; the sand fractions included very coarse (2 - 1 mm), coarse (1 - 0.5 mm), medium (0.5 - 0.25 mm), fine (0.25 - 0.10 mm), and very fine (0.10 - 0.05 mm). Soil textural classes are those developed by the USDA, Soil Conservation Service.

Chemical analyses were made on the less than 2 mm material from the profiles at Blueberry Hill. A strong acid mixture (HNO_3-HCl 0.75M) was used for extraction of the various elements, and an ICAP was used to determine the individual elements.

RESULTS AND DISCUSSION

Table 1 gives the soil morphology of the profiles described at Blueberry Hill. The soils are developed in very sandy sediment in a sand dune position. The upper portion of the profiles shows little soil development in terms of features such as argillic or cambic diagnostic horizons. The Bw described in the

upper meter of each profile indicates some iron translocation and weak structural development. Surfaces, however, have organic matter accumulation as evidenced by the darker colors and associated properties. The thickened A horizon evident in the profile described in unit 79 (Profile S91DE1) is probably the result of erosion or more rapid deposition of æolian sediment to the lee side of the dune.

The major feature of the soil sequences in the profiles is the buried B horizon occuring at depths near the surface (Profile S92DE2) to more commonly below one meter (Profile S91DE1, S92DE1). The Bt horizon had thin, nearly continuous clay coating and weak to moderate subangular blocky structure. The thickness of the solum (A and B horizons) of this paleosol ranged from 55 to 100 cm; truncation of some of the paleosols has probably taken place during the early Holocene soils. This may account for some of the increases in the paleosol B.

The P content was generally higher in the surface horizons of the soil and decreased with depth. Some increases in the paleosol may be related to translocation, but the sample size was not sufficient to establish a background level for the paleosol.

Blueberry Hill appears to be a complex landscape where Holocene dune activity has occurred over an early Holocene or Pleistocene surface. The older surface has a rather well developed paleosol that indicates a weathering period of at least 7,000 to 8,000 years. The soils developed on the dune material show minimal development in terms of B horizon morphology; these would be classified as entisols in Soil Taxonomy, USDA Soil Conservation Service. Although entisols, these soils show evidence of the following pedogenic processes:

1. Organic matter accumulation in A horizons
2. Some iron mobilization and translocation to B horizons
3. Weak structural development in the solum
4. Recycling of some elements (Ca, Mg, Mn, Ba, S, and Sr)
5. Accumulation of pollutants in surface horizons (As, Cd, Pb, Cu, and Zn)
6. Development of lamellae at the interface between the dune material and paleosol

The paleosol located at a depth of generally 90 to 120 cm below the surface in probably associated with a weathering period during the early Holocene or more likely the late Pleistocene. The presence of a moderately developed argillic horizon provided the bases for the age estimation. The paleosol observed in most locations has probably been truncated as evidenced by a small area where the nearly complete profile was observed (Profile S92DE2, ER 140). The soil chemical analyses indicate that the paleosol was at or near the surface for some time; the main evidence for this shows up in the presence of nutrients commonly recycled in soil systems (e.g. Ca, Ba, S, Sr).

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Horizon	Depth cm	Color	Mottles	Texture	Structure	Boundary
Profile S91DE1 (ER 79):						
A1	0-9	10YR 3/2, 5/4	none	ls	0sg	cs
A2	9-18	10YR 3/2	none	ls	0sg	cs
A3	18-30	10YR 3/3	none	ls	0sg	as
A4	30-48	10YR 4/3	none	ls	1fpl,sg	as
Bw1	48-75	10YR 5/6 (6/3)	none	ls	1msbk,sg	cs
Bw2	75-90	10YR 5/6, 4/6	none	ms	0sg	gs
BC	90-105	10YR 5/6, 5/4 (6/3)	none	m-cs	0-sg	-
C1	105-120	10YR 5/6	none	sl		
2Bt	120-160	10YR 5/8	none	sl		
		7.5YR 5/6				
2BC	160-175	7.5YR 5/3	m2f	l		
			7.5YR 5/6			
2C3	175-185	7.5YR 4/4, 4/6	none	sl		
2C4	185-205	7.5YR 4/4,4/6	none	m-cs		
Notes: Profile described on north face; upper 9 cm apparently mixed with local sands from local traffic; the A horizon at 30-48 cm was compact, the horizons above 48 cm appear to be the result of slow accumulation of sediment from wind erosion, some inclusions of darker colored material were evident in some areas; an older paleosol occurs at 120 cm.						
Profile S91DE2 (ER 82):						
A1	0-5	10YR 3/2	none	ls	0sg	cs
		some 5/6, 5/4				
A2	5-20	10Yr 3/2	none	ls	0sg	as
Bw	20-37	10YR 5/6	none	ls	0sg	gs
BC	37-54	10YR 5/6, 5/3	none	s	0sg	cs
C	54-75	10YR 5/4	none	s	0sg	-
Notes: Profile was described on west face; less thickness of A horizon was evident on this side of the site.						
Profile S91DE3 (ER 75):						
A1	0-15	10YR 3/3, 5/6	none	ls	1mpl,0sg	gs
A2	15-34	10YR 3/2	none	ls	1mabk, 0sg	as
Bw1	34-54	10YR 4/6	none	ls	1fsbk,0sg	cs
				sl		
BC	54-75	10YR 4/6, 5/6	none	ls	1msbk,0sg	cs
C1	75-90	10YR 5/6,6/6	none	ms	0sg	cs
2BC	90-100	10YR 4/6, 6/6	none	sl	0sg	os
2Bt1	100-125	10YR 4/6	none	l		
2Bt2	125-140	10YR 4/6	none	sl		
2BC	140-155	10YR 5/6	none	ls		
2C2	155-180	10YR 6/6	f1f	s		
			10YR 5/8			
2C3	180-205	10YR 6/4	f1f	ms		
			10YR 5/8			
Notes: Profile described on east face; A2 lower boundary tonguing into Bw1; paleosol noted at 90 to 155cm.						

Table 1, part 1
Profile descriptions of soils at the Blueberry Hill Site

Horizon	Depth cm	Color	Mottles	Texture	Structure	Boundary
Profile S92DE1 (ER 85):						
Ap	0-30	10YR 3/2	none	ls	0sg	as
Bw	30-55	7.5YR 5/6, 4/4	none	ls	-	-
C1	55-85	7.5YR 4/6 lamellae (3 mm thickness) 7.5YR 5/6, 6/6 interlamellae				
2Bt	85-130	7.5YR 4/4	flf 7.5YR 4/6	scl	-	-
2BC	130-150	7.5YR 5/4, 5/6	m2d 7.5YR 5/8	sl	-	-
2C1	150-180	10YR 5/6, 6/6	m2d 7.5YR 5/8 (5% gravels)	ls	-	-
2C2	180-200	10YR 6/6, 5/6	m2d 7.5YR 5/8	s	-	-
2C3	200-230	10YR 7/3	m2d 7.5YR 5/8	s	-	-
Notes: Profile described near the center of unit 85; auger used to determine the thickness of 2Bt horizon; lamellae developed above the 2Bt were thin, but they were nearly continuous.						
Profile S92DE2 (ER 140):						
Ap	0-45	10YR 3/2	none	ls	-	-
BE	45-60	7.5YR 4/4, 5/4, 6/4 (20%)	none	sl	-	-
Bt1	60-110	7.5YR 4/4	none	scl	-	-
Bt2	110-140	7.5YR 4/4, 4/6	none	scl	-	-
BC	140-160	7.5YR 5/6	m2f 7.5YR 5/8	sl	-	-
C1	160-190	7.5YR 6/6	m2d 7.5YR 5/8	s	-	-
C2	190-230	10 YR 6/4	fld 10YR 5/8	s	-	-
Notes: Described in center of unit 140; thin, nearly continuous clay coatings in Bt horizon; this is the only location where the paleosol is near the surface; erosion appears to have left a small remnant of the paleosol Bt protruding above the dune sand.						
Profile S92DE3 (ER 162):						
Ap	0-40	10YR 3/2	none	ls	1fpl	as
Bw	40-55	7.5YR 5/6, 4/6	none	ls	1mpl	cs
C	55-93	7.5YR 4/6 lamellae 7.5YR 6/4, 6/6		s-ls	0sg	as
2B&C	93-105	7.5YR 5/6 7.5YR 4/6, 4/4 lamellae	none	ls	0sg	cs
2B	105-120	7.5YR 4/6	none	scl	1-2 msbk	-
Notes: Profile described on west face; clay skins in 2Bt						

Table 1, part 2
Profile descriptions of soils at the Blueberry Hill Site

PARTICLE SIZE ANALYSIS: PIPETTE METHOD.

LAB #	HORIZ.	DT	DB	MIDP	USDA TEXT. CLASS	VCOS 2000-1000	COS 1000-500	MS 500-250	FS 250-100	VFS 100-50	SAND 2000-50	SILT + CLAY
				cm		Size Class and Particle Diameter (PERCENT)						
				0.0		ERR	ERR	ERR	ERR	ERR	ERR	ERR
S91DE-1												
1	A1	0	9	4.5		4.1	29.7	25.2	19.9	1.4	80.4	19.6
2	A2	9	18	13.5		4.1	30.4	23.3	20.1	1.2	79.0	21.0
3	A3	18	30	24.0		3.8	27.7	25.3	22.6	8.0	87.4	12.6
4	A4	30	48	39.0		3.9	28.9	24.6	22.0	2.2	81.6	18.4
5	Bw1	48	75	61.5		5.5	32.2	23.9	20.0	2.6	84.2	15.8
6	Bw2	75	90	82.5		4.6	28.6	27.6	24.3	2.3	87.4	12.6
7	BC	90	105	97.5		6.6	33.2	27.0	20.0	1.4	88.2	11.8
8	C1	105	120	112.5		5.6	33.3	18.0	17.2	1.9	76.1	23.9
9	2B?	120	160	140.0		3.3	21.5	22.2	19.0	2.4	68.5	31.5
10	2C2	160	175	167.5		2.7	21.1	16.3	12.7	2.2	55.0	45.0
11	2C3	175	185	180.0		3.3	25.2	20.8	15.5	2.2	67.0	33.0
12	2C4	185	205	195.0		5.7	32.6	22.0	18.2	1.9	80.5	19.5
S91DE-2												
1	A1	0	5	2.5		4.8	28.7	24.4	21.4	2.0	81.4	18.6
2	A2	5	20	12.5		3.1	26.3	25.7	24.9	2.1	82.1	17.9
3	Bw	20	37	28.5		4.8	30.2	26.6	21.8	2.0	85.5	14.5
4	BC	37	54	45.5		4.0	33.0	28.1	24.3	1.9	91.3	8.7
5	C	54	75	64.5		4.6	33.7	30.5	22.5	1.8	93.1	6.9
S91DE-3												
1	A1	0	15	7.5		5.0	30.8	25.9	20.7	1.9	84.3	15.7
2	A2	15	34	24.5		3.3	30.0	25.5	32.8	1.6	93.1	6.9
3	Bw1	34	54	44.0		5.6	31.5	23.8	19.2	1.8	82.0	18.0
4	BC	54	75	64.5		3.9	35.7	22.8	19.4	2.4	84.2	15.8
5	C1	75	90	82.5		7.5	32.1	23.7	17.9	2.5	83.6	16.4
6	2BC	90	100	95.0		7.2	29.1	20.7	16.1	1.8	75.0	25.0
7	2Bw1	100	125	112.5		4.4	20.8	19.6	16.3	2.3	63.3	36.7
8	2Bw2	125	140	132.5		1.6	25.6	21.3	20.2	2.9	71.6	28.4
9	2BC	140	155	147.5		6.3	32.6	25.4	22.3	1.8	88.3	11.7
10	2C2	155	180	167.5		2.8	27.0	27.0	35.4	1.9	94.2	5.8
11	2C3	180	205	192.5		2.3	23.0	30.9	37.7	4.2	98.2	1.8

Table 2
Particle size analyses of profiles at site 7K-C-107

Horizon	Depth cm	Elemental Analysis (ppm)														
		Al	Ca	Mg	K	Fe	P	Pb	Mn	Ba	S	Sr	Zn	As	Cd	Cu
Profile S91DE1																
A1	0-9	715	400	37	41	468	24	18	57	18	20	4.4	8.2	0.7	0.4	2.1
A2	9-18	928	293	23	36	717	29	12	54	18	23	3.7	7.3	1.2	0.2	2.0
A3	18-30	829	107	8	25	519	27	7	23	10	22	1.5	4.3	0.9	0.1	1.3
A4	30-48	839	169	12	26	487	19	8	22	13	13	2.0	1.3	0.5	0.1	0.9
Bw1	48-75	394	28	4	11	235	10	tr	1	9	11	0.3	0.2	tr	tr	0.4
Bw2	75-90	312	15	4	12	158	21	tr	2	7	9	0.2	tr	tr	tr	tr
BC	90-105	240	32	10	12	131	18	tr	2	9	7	0.4	0.1	tr	tr	tr
C1	105-120	417	120	37	23	201	18	2	1	16	10	1.4	0.2	tr	tr	0.7
2B?	120-160	618	112	21	22	346	24	3	1	17	36	1.5	0.4	tr	tr	0.7
2BC?	160-175	714	102	24	22	301	16	3	1	20	50	1.2	0.5	0.5	0.1	0.8
2C2	175-185	533	67	16	15	280	8	3	1	12	61	0.7	0.4	tr	tr	0.5
2C3	185-205	350	59	16	15	295	115	2	4	11	33	0.7	0.5	tr	tr	1.2
Profile S91DE2																
A1	0-5	582	64	8	29	357	32	8	20	8	13	1.1	2.2	0.6	0.1	0.9
A2	5-20	718	89	5	17	411	33	5	20	10	19	1.5	2.1	0.9	0.1	1.0
Bw	20-37	389	34	6	11	210	13	1	6	7	7	0.3	0.1	tr	tr	0.3
BC	37-54	261	16	4	11	168	13	tr	1	5	8	0.2	0.1	tr	tr	0.3
C	54-75	229	8	2	7	112	24	tr	1	5	7	0.1	0.2	tr	tr	tr
Profile S91DE3																
A1	0-15	502	142	17	18	277	25	5	17	8	15	1.5	2.1	0.6	0.1	0.7
A2	15-34	800	86	6	22	457	31	6	22	10	22	1.2	1.6	1.0	0.1	1.0
Bw	34-54	946	36	6	19	435	15	2	3	6	13	0.4	0.3	0.8	0.1	0.4
BC	54-75	667	40	6	12	481	18	2	1	6	13	0.4	0.1	0.6	0.1	0.3
C1	75-90	448	22	5	16	237	18	1	3	7	10	0.2	0.2	0.4	tr	0.3
2BC	90-100	526	184	41	48	230	13	2	1	18	11	1.9	0.2	0.5	tr	0.3
2Bw1	100-125	670	221	40	41	237	15	3	1	21	29	2.9	0.3	0.5	tr	0.5
2Bw2	125-140	581	177	30	22	282	16	3	1	15	42	2.3	0.3	0.4	tr	0.5
2BC	140-155	360	86	15	13	143	10	1	1	9	36	0.9	0.1	tr	tr	0.3
2C2	155-180	193	45	8	8	78	6	1	1	4	21	0.4	tr	tr	tr	tr
2C3	180-205	100	35	8	8	38	4	tr	1	3	7	0.3	tr	tr	tr	tr

Table 3

Chemical analysis of soil profiles at site 7K-C-107