APPENDIX 2

SOIL STUDIES OF BLUEBERRY HILL, 7K-C-107 AND WHITE MARSH, 7K-C-390

BY JOHN E. FOSS
SOIL SCIENTIST

SOILS INTERNATIONAL, INC.

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INTRODUCTION

The soils study is concerned primarily 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 located on a sand dune that has apparently been preserved from large-scale disruption; surrounding areas show evidence of construction influence of the railroad, recreational activities, and other functions that could cause instability and erosion.

Sand dunes are quite common in Delmarva, but Denny and Owens (1979) have placed a date of 30,000 to 13,000 years B.P. for most of the dunes. Denny and Owens did suggest that some of the dunes may be Holocene, however.

A number of excavations and auger borings were also made at the White Marsh site to determine the general soil stratigraphy and pedologic history. This site was located on sandy sediments overlying gravelly material.

The objectives of the soils study were [1] describe the morphology of the major soils at Blueberry Hill and White Marsh, [2] determine the physical properties of soil at Blueberry Hill, [3] study the chemical properties of soil at Blueberry Hill, and [4] present a general pedologic history of the two sites.

METHODS

The soils were described 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 the Soil Conservation Service, USDA.

Particle size analysis was accomplished by sieving the sample through a 10-mesh screen (2mm 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).

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

RESULT AND DISCUSSION

Soil Morphology

White Marsh

The morphological descriptions of the soils examined at White Marsh are given in Table 1. Profile [ER] 103, described on a toe

slope of an upland terrace, has 103 cm of recent sediment over a buried Ab horizon. From preliminary analysis, the buried Ab horizon is associated with the original surface prior to the beginning of intensive agriculture in the region. Several other intervals of stability within the upper 90 cm are indicated by weakly developed A horizons (eg 20-23 cm and possibly 49-61 cm).

Profile [ER] 104, upslope from 103, is developed in sandy sediments overlying a gravelly component. Possible truncation of profile 104 is suggested by the abrupt contact with lamellae immediately below the Ap. The well-developed lamellae (color and thickness) indicate appreciable length of weathering; a period of 7,000 years is suggested based on soil morphology.

Profile [ER] 105, at nearly the same elevation as profile 104, is similar in characteristics to the previous profile, specifically, well developed lamellae and the gravelly material encountered at 95 cm.

Blueberry Hill

Table 2 gives the soil morphology of three profiles sampled and described at Blueberry Hill. The soils are developed from very sandy sediment in a sand dune position. The soils are weakly developed with minimal horizonation in the upper meter. Profile [ER] 79 (lab number DE 1), for example, shows a thickened A horizon to 48 cm and a weakly developed B horizon with some indication of iron translocation (color B). The thickened A horizon is probably the result of erosion or more rapid deposition of æolian sediment to the lee side of the dune. The A horizon thickens toward the lee side of the dune in this profile.

An interesting feature of profiles 79 and 75 (DE 2) is the buried B horizon occurring at 100 to 120 cm. The thickness (50 to 60 cm) and development of this buried B horizon indicates a period of stability for perhaps 7,000 or 8,000 years. Examination of the buried B horizon was accomplished by auger samples; a more detailed description is needed in a pit face to determine structure and the presence of clay skins or coatings.

Laboratory Analysis

Particle Size Analysis

Table 3 gives the particle size distribution of the profiles sampled at Blueberry Hill. As noted in the table, the soils are very sandy with total sand content ranging from 55.0% to 98.2%. The upper meter in all three profiles averaged 85.2% sand, while the buried paleosol had an average of 68.3% sand. No major discontinuities are evident in the upper meter in the three profiles. In profile 79, a major discontinuity occurs between 105 and 120 cm or just above the paleosol B horizon. In profile 75 a discontinuity also occurs above the paleosol B horizon.

Chemical Analysis

Table 4 shows the results of elemental analysis of the three soil profiles studied at Blueberry Hill. Those heavy metals considered pollutants, such as Pb, Zn, Cu, As, and Cd show considerable accumulation in the surface horizons (A horizons) of all three profiles. Some recycling of elements by vegetation is also evident in the case of Cu and Zn (somewhat for Pb); note the increase in these two elements in the paleosols at 1.5 and 1.0 meter in profiles 79 and 75, respectively. Cadmium (Cd) appears to be mainly the result of pollution.

A number of elements are recycled by plants and generally show accumulation in the surface horizons. Those elements that appear to be closely associated with this recycling activity are Ca, Mg, S, Mn, Ba and Sr. The content of Ca, Mg, S, Mn, Ba, and Sr is shown to be the highest level in the A horizons of the soil occuring in the upper meter; most of these elements also show increases in the paleosol. This supplies some evidence that the paleosol had the influence of vegetation recycling nutrients to surface horizons. The soils were coarse textured and thus some translocation of nutrients would be expected in these soils.

The P content generally showed maximum levels in the surface A horizons and a decrease with depth in the profiles. A slight increase in the paleosol B horizon may be related to differences in texture; additional

samples will be needed to determine normal background levels of P in the paleosol.

SOIL GENESIS OF BLUEBERRY HILL

In a preliminary analysis, Blueberry Hill appears to be a complex landscape where Holocene dune activity has occurred over an early Holocene or Pleistocene surface. The dune material is very sandy with sand contents averaging 85.2%; most of the sand, approximately 40% to 55%, occurs in the coarse and medium fractions (1 to 0.25 mm). The soils developed on the dune show minimal development and would be classified as Entisols in the USDA Soil Taxonomy system. Although Entisols, these soils do 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, S, Mn, Ba, and Sr)
5. Accumulation of pollutants in surface horizons (As, Cd, Pb, Cu, and Zn)

The paleosol located at a depth of 90 to 120 cm below the surface is probably associated with the early Holocene or late Pleistocene. Because the characteristics described were from auger borings, structure and clay skins could not be determined. This paleosol may be associated with adjoining landscapes, but additional study is needed to determine age and relationships with surrounding soils. The soil chemical analyses, however, indicate that the paleosol was a surface at some time; the main evidence for this shows up in the recycling of nutrients (e.g. Ca, Mg, S, Ba, Sr).

REFERENCE

Denny, C. S., and J. P. Owens

1979 *Sand Dunes on the Central Delmarva Peninsula, Maryland and Delaware.* Geological Survey Professional Paper 1067-C. U. S. Government Printing Office, Washington.

TABLE 1

PROFILE DESCRIPTIONS OF SOILS AT WHITE MARSH ARCHÆOLOGICAL SITE.

Horizon	Depth cm	Color	Mottles	Text.	Struct.	Bound.
Profile 103						
A	0-4	10YR 3/1	None	sl		
C1	4-20	10YR 4/3	None	sl		
2A	20-23	10YR 3/1	None	ls		
2C2	23-49	10YR 4/3,6/4	None	ls		
2A?	49-61		None	ls		
2C3	61-90		None	ls		
3Ab	90-103	10YR 3/3	None	sl		
3AB	103-120	10YR 4/4	None	ls		
3Bw	120-135	7.5YR 4/4,4/6	None	ls		
3C4	135-150		Mottled	ls		
4Bw1	150-165		"	sl		
4Bw2	165-190	2.5YR 4/8,6/2 7.5YR 5/6	"	scl		

Notes: This profile is located on a toe slope of a terrace where a great deal of historic erosional deposition has taken place; the buried Ab at 90-103 cm is probably the original surface before cultivation; the 4Bw or Bt at 150-190 cm is a old surface, probably developed during Pleistocene

Profile 104

Ap	0-26	Similar to Ap in profile 103				
E & B	26-85	Lamellae; light colored 10YR 5/6 dark colored 7.5YR 4/4, 5YR 4/4				
C	85-100	Gravelly sediment				

Notes: This profile appears to be truncated; profile was formed in dune-like material; lamellae were well developed (3-4 cm in thickness) and quite red (strong brown to reddish brown), this indicates appreciable weathering time e.g. 7,000 years+

Profile 105

Notes: Profile is similar to Profile 104, with some lamellae in lower portion of profile above the gravelly material at 95 cm

TABLE 2

PROFILE DESCRIPTIONS OF SOILS AT BLUEBERRY HILL

Horizon	Depth cm	Color	Mottles	Text.	Struct.	Bound.
Profile S91DE1 (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 (6/4)	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		
2Bw?	120-160	10YR 5/8 7.5YR 5/6	None	sl		
2BC?	160-175	7.5YR 5/3	m2f 7.5YR 5/6	l		
2C3	175-185	7.5YR 4/4,4/6	None	sl		
2C4	185-205	7.5YR 4/4,4/6	None	m-cs		
Notes: Proile 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 (82)						
A1	0-5	10YR 3/2 some 5/6,5/4	None	ls	0sg	cs
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 (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 sl	1fsbk,0sg	cs
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	gs
2Bw1	100-125	10YR 4/6	None	l		
2Bw2	125-140	10YR 4/6	None	sl		
2BC	140-155	10YR 5/6	None	ls		
2C2	155-180	10YR 6/6	f1f 10YR 5/8	s		
2C3	180-205	10YR 6/4	f1f 10YR 5/8	ms		
Notes: Profile described on east face; A2 lower boundary tonguing into Bw1						

TABLE 3

PARTICLE SIZE ANALYSIS OF PROFILES AT BLUEBERRY HILL

PARTICLE SIZE ANALYSIS: PIPETTE METHOD.

o #'s:1-1--3-11

roject:Delaware Dune Project

LAB #	HORIZ.	DT	DB	MIDP	USDA TEXT. CLASS	Size Class and Particle Diameter (PERCENT)						
				cm		VCOS 2000-1000	COS 1000-500	MS 500-250	FS 250-100	VFS 100-50	SAND 2000-50	SILT + CLAY
				0.0		ERR	ERR	ERR	ERR	ERR	ERR	ERR
PIDE-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
PIDE-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
PIDE-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 4

CHEMICAL ANALYSIS OF SOIL PROFILES AT BLUEBERRY HILL

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