Nature and Properties of Some Forest Soils in the White Mountains of New Hampshire

by M. C. Hoyle

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NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

The Author

DR. MERRILL C. HOYLE, plant physiologist, has been employed by the Northeastern Forest Experiment Station since 1961. He earned the B.S. and M.S. degrees at the University of Massachusetts, and Ph.D. degree at the University of New Hampshire.

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Abstract

Forested, podzol soils in the White Mountains of New Hampshire have developed in granitic, glacial material. They are coarse textured, acidic, and infertile. As a result of the latter condition, these soils can sustain a forest, but that forest is not healthy and vigorous.

INTRODUCTION

Not much information is available on the nature and properties of forest soils in the White Mountains. The need for soils information is increasing because the mountains are being used more intensively for outdoor recreation, while the forest continues as an important source of water, wood products, and wildlife. Management of the forest for natural products and an aesthetically pleasing environment will be successful to the degree that we understand the capabilities of the forest soil. Soil, climate, and the acts of men are the main determinants of the forest ecosystem. We cannot alter the climate, but the acts of men can be governed and the soils can be managed. The information given in this paper contributes to our further understanding of some selected forest soils that occur widely throughout the White Mountains.

METHODS AND MATERIALS

Soil Descriptions

Soil descriptions (see Appendix) were prepared by soil scientists from the Soil Conservation Service.[1] Nomenclature follows that given in the Soil Survey Manual of the USDA Bureau of Plant Industry, Soils, and Agricultural Engineering (1951).

Sample Collection and Preparation

All soil samples were collected on the Bartlett Experimental Forest in Bartlett, New Hampshire. (See map in Appendix for exact location.) One-foot squares of the forest floor were cut out and separated into L (litter), F (fermented), and H (humus) layers. The depths of these layers were estimated by taking the mean of numerous measurements around the walls of the square-foot section. Volumes were then calculated for each layer. Six 60-ml. core samples were taken for each mineral horizon.

All samples were air-dried. Then the organic samples were ground, and the mineral samples were each separated by sieving into a greater-than-2 mm. fraction and a less-than-2 mm. fraction. Since all analyses were made on the air-dried, less-than-2 mm. fractions, corrections were applied later to produce values for the coarse material and the oven-dry condition.

Soil Analyses

Soil moisture content at 0.06 atm. was measured with a mercury manometer in the Buechner funnel method of Wilde and Voigt (1955). Soil pH was determined with a glass electrode in a soil paste. Textural analyses were made with a Bouyoucus hydrometer. And organic matter was estimated by loss on ignition.

Exchangeable sodium, potassium, magnesium, and calcium were extracted with neutral, N NH_4OAc and measured by flame photometry. Exchangeable hydrogen and aluminum were extracted with N KCl and estimated by titration to pH 4 and pH 8.3, respectively (Coleman, Weed, and McCracken 1955).

[1]The author gratefully acknowledges the assistance of Sidney Pilgrim and Frank Viera (SCS, Durham, N. H.), and Robert Reiske (BLM, Washington, D.C.)

RESULTS AND DISCUSSION

Forest Composition

Forests in the area around the soil pits described in this paper are primarily hardwood with a softwood component of from 0 to 20 percent (table 1). The forest around soil No. 15 is mainly softwood. The dominant trees on all plots are between 60 and 100 years old, between 60 and 80 feet tall, and average only about 0.1 inch per year in diameter growth.

Table 1.—*Composition of forests in plots where soils were examined (trees 6 inches d.b.h. and greater)*

Soil No.	Hardwoods[a]	Softwoods[b]
	Percent	*Percent*
1	91	9
3	97	3
4	80	20
11	85	15
15	31	69
17	100	0

[a]Primary species: beech, red maple, sugar maple, yellow birch, paper birch, white ash.
[b]Primary species: red spruce, balsam fir, hemlock.

Forest Floor

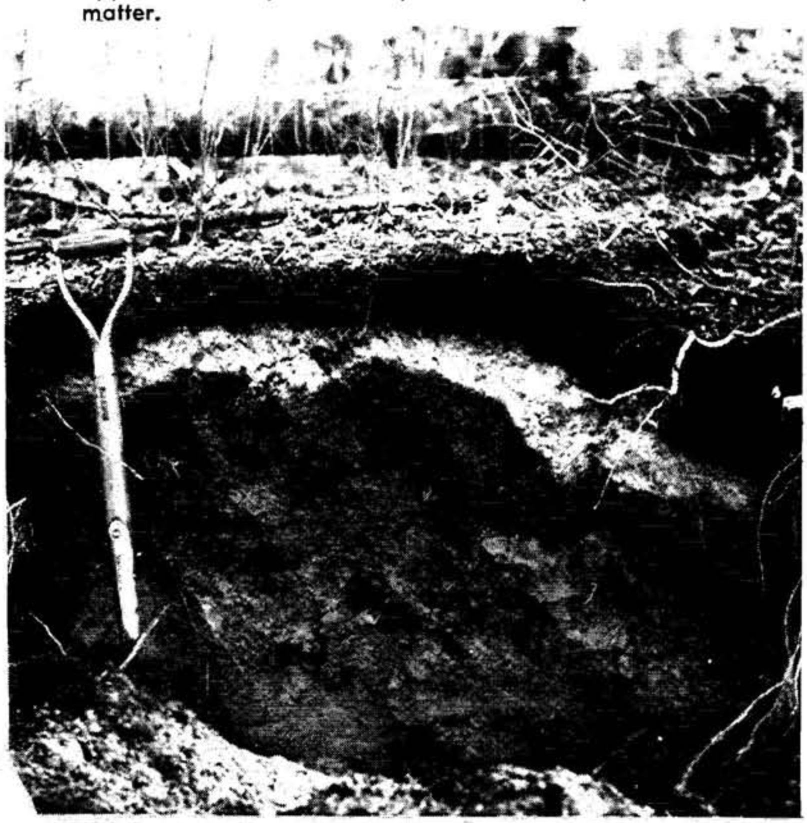
The forest floor on all soils is typically mor, with its three layers of L (litter), F (fermented), and H (humus). Under the predominantly hardwood forests the H layer is thin (½ to 3 inches), but under the predominantly softwood forest the H layer is 13 inches thick. This large difference in the depth of the H layer is a result of the difference between the microclimate under hardwoods and that under softwoods. The forest floor is warmer and drier under hardwood forest than under softwoods, conditions that generally favor breakdown of organic detritus over accumulation. As a consequence, the *available* nitrogen, for tree growth, is generally higher in the forest floor of hardwood stands.

Mineral Soil

All soils developed in glacial till or glacial outwash laid down during the Wisconsin age. Rocks are abundant, both in the soil and scattered over the surface. The rocks are granitic and contain orthoclase feldspar, quartz, muscovite mica, biotite mica, and small amounts of other minerals. Chemically, these minerals contain potassium aluminosilicate, silica, potassium aluminosilicate with hydroxyl group, and potassium (ferromagnesium) aluminosilicate with hydroxyl group, respectively. These minerals weather slowly and have produced coarse-textured sandy soils of low fertility. The clays are probably kaolinitic. There is little development of structure in the soils. Most soils are classified as weak, fine granular. In the Becket soil (no. 17) and the poorly drained soil (no. 11), pans are present. This massive structure causes lateral flow of water through the soil.

In the well-drained soils, there is a strong profile development (fig. 1) that is typical of podzols. However, some of the soils have been repeatedly disturbed by windthrow (e.g., soil no. 1) so horizons have been mixed and/or

Figure 1.—A well-developed podzol profile showing the characteristic gray, leached horizon (A2) above the reddish-brown horizon (B2) of Fe and Al accumulation. The upper black layer is composed of decayed organic matter.



buried. As a result, the colors are not of their usual intensity and the horizons show an unusual sequence. In general, though, the distinct ashy gray A2 and the reddish-orange B2 horizons are quite distinct. In many soils, iron has accumulated in the B2 to a considerable degree and some ortstein (iron pan) is present.

In poorly drained soils, olive gray to mottled gray colors of the gley layers are found. These horizons develop as a result of reducing conditions when water drainage is impeded and oxygen content is very low.

Physical Properties (Tables 2 and 3)

Bulk density varies greatly, from a low of 0.1 g/cc. in humus to a high of nearly 1.7 g/cc. in the C horizons. The general trend is

Table 2.—*Physical properties of soils*

Horizon	Bulk density	Textural analyses			Sand separates				
		S	Si	C	VCS	CS	MS	FS	VFS
	g./cc.				Percent				
Soil No. 1 Berkshire									
H	0.27	—	—	—	—	—	—	—	—
A2	1.16	50.9	27.2	2.3	13.5	16.7	11.1	32.3	26.5
B21h	.78	63.8	23.8	.4	7.9	18.5	15.4	34.2	24.1
B21ir	.87	54.8	23.8	.3	12.0	17.8	13.1	33.7	23.3
B22	1.32	62.9	30.0	.8	14.4	14.4	10.9	33.5	26.8
A2b	1.34	46.6	34.9	1.0	11.9	11.3	9.4	34.6	32.8
B21b, B22b	1.31	53.6	18.7	3.4	14.9	14.8	12.5	33.2	24.6
B3b	1.46	57.6	16.9	1.8	1.9	19.4	11.8	29.2	20.5
C1, C2	1.49	56.7	28.6	1.8	9.2	9.5	9.2	35.1	37.0
Soil No. 3 Acton									
H	.30	—	—	—	—	—	—	—	—
A2	1.32	45.7	40.0	2.5	8.8	9.7	7.8	31.8	41.9
B21h, B22ir	.98	62.7	20.5	.7	13.9	13.9	17.1	32.1	23.0
B23, B24	1.32	54.2	20.7	0	18.9	17.9	13.2	27.6	20.2
B3, C	1.50	53.8	20.9	.9	13.3	14.5	13.3	35.3	24.1
Soil No. 4 Berkshire									
H	.27	—	—	—	—	—	—	—	—
A2	1.20	52.0	40.3	2.3	5.9	11.3	11.7	37.3	33.7
B21h	.97	64.8	16.0	.6	15.5	24.8	15.4	27.9	16.4
B22ir	1.11	60.2	17.9	0	15.4	18.0	14.9	31.5	20.2
B23, B24	1.37	56.4	19.2	0	13.3	14.5	13.3	35.3	24.1
B3	1.34	60.1	27.4	.4	9.8	13.7	11.2	36.2	29.0
C1	1.66	55.4	31.4	0	10.1	12.6	10.8	36.0	30.5
Soil No. 11 Undetermined series									
H	.08	—	—	—	—	—	—	—	—
A1	.43	77.8	14.2	2.7	21.0	22.5	11.6	41.0	3.8
A2g	1.61	62.6	21.3	4.2	12.5	17.6	17.6	34.0	18.4
Cg1	1.65	62.6	17.4	3.4	17.1	18.8	15.8	32.8	15.5
Soil No. 15 Croghan									
H	.06	—	—	—	—	—	—	—	—
A2	1.11	78.5	20.8	0	3.3	10.9	20.1	54.7	14.3
B21h	.93	85.4	10.4	.8	4.3	15.0	21.5	43.4	8.9
B22ir	1.21	88.4	4.3	1.6	14.7	31.9	35.3	27.0	1.4
B23ir	1.37	89.0	2.0	2.7	3.8	12.6	29.0	51.2	4.9
B24	1.43	90.2	1.9	4.3	14.6	30.5	23.0	27.5	5.2
B3	1.34	74.8	24.9	0	1.6	6.3	14.3	45.0	27.8
C1, C2	1.31	74.2	17.7	.8	16.1	23.4	18.1	29.5	12.8
Soil No. 17 Becket									
H	.24	—	—	—	—	—	—	—	—
B2ir	.95	54.0	26.0	0	15.0	18.4	14.7	31.4	20.4
B&A	1.36	46.5	13.6	1.0	19.4	18.0	14.1	29.8	18.7
C1x, C2	1.43	57.5	22.6	.3	16.1	17.3	12.0	32.0	22.7

Table 3.—*Volumes of air and water in various horizons of representative podzol soils on the Bartlett Experimental Forest*

Horizon	Pore volume	Water volume	Air volume
	Percent	*Percent*	*Percent*
Soil No. 21 Hermon (well drained)			
H	95.9	45.2	50.7
A2	63.4	46.0	17.4
B22h	72.8	43.3	29.5
B23	63.7	38.3	25.6
B3	54.7	28.3	26.4
C	46.1	25.0	21.1
Soil No. 22 Hermon (well drained)			
H	89.6	18.2	71.9
H-A2	65.3	32.1	33.2
B22	64.5	35.0	29.5
B23	51.0	27.9	23.1
B3	52.8	27.3	25.5
B3C	47.8	12.0	35.8
Soil No. 23 Waumbek (moderately well drained)			
H	83.4	36.9	46.5
A2	51.3	32.4	18.9
B2h	62.4	28.9	33.5
B22	51.0	32.4	18.6
B23	42.3	9.2	33.1
B3g	46.1	25.6	20.5
Soil No. 24 Whitman (poorly drained)			
H	91.7	23.8	67.9
A	66.8	36.6	30.2
G	(massive, could not take core sample)		

for bulk density to increase with greater depth, but this trend is altered in B2 horizons where organic matter accumulates (table 5).

The soil horizons are all coarse-textured, and may contain as much as 90 percent sand, but sand content usually ranges between 50 and 70 percent. Fifty to sixty percent of the sand is composed of fine and very fine fractions, and the remaining 40 to 50 percent is about equally divided among the very coarse, coarse, and medium sand fractions. Clay content is very low, and varies from 0 to only 4.3 percent.

As a consequence of this coarse texture, the glacial soils are quite porous (table 3), except where iron pan develops in B2 horizons or silt pans form in the lower B or C horizons (e.g., in a Becket soil). Total porosity varies from 40 to 70 percent in the mineral horizons and is estimated at 80 to 90 percent in humus layers of the forest floor. At field capacity (water retained against a tension of 0.06 atm.), the pores are occupied by water and air about equally, but in some horizons there is a considerable departure from this generalization. Very often the A2 horizons will show some resemblance to a platy structure and the air volume at field capacity may be down to 17 percent (e.g., soil nos. 21 and 23, table 3). An air volume of 15 percent is thought to be the limit for good root development. However, since the pore volume occupied by water is constantly changing, the air volume must change also.

In terms of water-holding capacity, these water volume percentages translate into 10 to 15 inches of total water for a 30-inch depth of typical glacial soil in the White Mountains. The high porosity of these soils also indicates that percolation rates are high. In areas where these highly porous soils are underlain by hardpan, landslides are quite common (fig. 2).

Figure 2.—A recent landslide in Franconia Notch. Deciduous trees colonize these new slide areas and conifers follow much later. The sites of older landslides are marked by deciduous trees in the photograph.

Chemical Properties (Tables 4 and 5)

All of the soils are very acidic (table 4). Surface horizons vary from pH 3 to 4 and subsoil horizons vary between pH 4 and 5.5. Humus horizons are extremely acid and may go below pH 3 (e.g., soil no. 15, table 4).

Contrary to general belief, it is the large quantity of exchangeable aluminum (Al), and not hydrogen (H), that is the primary cause of high acidity throughout the profile of these soils (tables 5 and 6). Exchangeable H is found only in the humus and A2 layers of soils with good drainage, and is not detected in poorly drained soils (tables 5 and 6). Consequently, H contributes only in part to acidity in the surface soil and not at all to acidity in the subsoil.

The quantity of exchangeable cations (i.e., NA^{+}, K^{+}, Mg^{++}, Ca^{++}, Al^{+++}) in these podzol soils is a reflection of the mineralogy of the parent rock, the low base exchange capacity, the severity of leaching by rainwater, and the annual deposition of leaves on the forest floor.

Potassium and Al are weathered from orthoclase feldspar (the predominant constituent of granite); Na, Ca, and Mg come from the white and black micas, and small amounts of other dark minerals. The total quantity of these nutrient-supplying minerals is small. The base exchange capacity (i.e., the sum of all exchangeable cations that can be adsorbed) of the mineral soil is also small because clay content is low. In addition, these mountain soils receive about 4 inches per month of rainfall so the cations in soluble phase are leached rather severely from the well-drained soils (e.g., nos. 1, 3, 15, and 21). Leaching of cations is somewhat retarded in soils with hardpan (no. 17) or soils with gley layers (soil nos. 11 and 24), so their quantities of exchangeable cations are higher.

The annual leaf fall in autumn counteracts this leaching effect, and the decomposition of leaves produces a higher cation content in the surface horizons than in the subsurface horizons. This phenomenon is known as nutrient cycling.

Calcium content is higher than that of the other elements in decomposing leaves because of the peculiarities of tree metabolism. Calcium not only accumulates in the foliage in greater quantities than Na, K, or Mg, but Ca is *not* translocated out of the foliage just before leaf fall as are large portions of the other elements. Aluminum, on the contrary, accumulates in tree roots and very little is carried into the leaves. Consequently, there is much less enrichment of Al in the soil surface than there would be if the metabolism of Al were the same as that of Ca.

In general, exchangeable Al in the soil is highest in the upper B horizons (soil no. 15, table 5, is a good example) where it accumulates, along with Fe, as a consequence of the normal podzolization process of soil weathering.

Before we leave the discussion of exchangeable cations, let me explain why two different units are used to express these quantities.

Historically, milliequivalents (meq.) per 100 grams of soil have been widely used in soil science to quantify exchangeable cations. These units have proved quite satisfactory in reference to the plow layer of agricultural soils because cultivation tends to produce a uniform bulk density across a wide range of soil types. Hence when milliequivalents for a plow layer are expressed on an equal weight basis (i.e., per 100 g.) it is usually true that the volumes of soil are equal also. But in forest soils there is no single homogeneous layer that can be examined to evaluate soil fertility. Tree roots develop in a number of horizons that differ widely in bulk density. There is a considerable difference in volume between 100 g. of humus and 100 g. of A2 horizon soil (table 2).

Therefore meq./100 g. soil *does not* provide a legitimate basis for comparing exchangeable cations[2] between horizons or between soils. By using bulk density, one can convert meq./100 g. of soil to meq/liter of soil and obtain an equal basis for comparison that is pertinent to a forest soil in its native state. For example, in table 4 it appears that there is

[2]Exchangeable cations make up a major fraction of each nutrient element in soil that is available to a plant, and their concentration often correlates well with tree growth.

Table 4.—*Soil Chemical properties (weight basis)*

Horizon	O.M.	Exchangeable cations						pH
		Na	K	Ca	Mg	Al	H	
	Percent	*meq./100 g. soil*						
Soil No. 1 Berkshire								
H	62.0	0.60	1.35	7.26	0.70	4.33	2.98	3.2
A2	2.3	.03	.08	.29	0	2.22	.24	3.8
B21h	15.7	.03	.12	.06	.05	5.46	.20	4.2
B21ir	9.7	.06	.06	.10	.03	—	—	4.7
B22	3.2	.03	.02	.09	0	—	—	4.9
A2b	1.9	.03	.02	.09	0	—	—	4.8
B21b, B22b	2.6	.03	.01	.08	0	—	—	4.8
B3b	1.5	.02	.02	.05	0	—	—	5.1
C1, C2	.8	.02	.01	.03	0	—	—	5.0
Soil No. 3 Acton								
H	48.6	.40	.95	7.21	1.02	3.31	1.63	3.4
A2	.6	.03	.04	.18	0	1.19	.11	4.0
B21h, B22ir	1.5	.03	.04	.36	0	—	—	5.0
B23, B24	1.3	.03	.02	.03	0	.44	0	5.1
B3, C	.4	.01	.01	.03	0	.17	0	5.2
Soil No. 4 Berkshire								
H	46.8	.49	1.22	2.13	.31	6.17	4.52	3.1
A2	2.4	.03	.06	.12	.05	1.68	.55	3.4
B21h	19.6	.03	.07	.02	0	—	—	3.9
B22ir	9.2	.03	.02	.04	0	.96	0	4.8
B23, B24	2.3	.02	.01	.06	0	.41	0	4.9
B3	2.5	.03	.01	.04	0	.41	0	4.8
C1	1.3	.03	0	.03	0	.37	0	4.9
Soil No. 11 Undetermined series								
H	25.6	.58	1.26	9.91	1.36	2.16	0	4.5
A1	21.4	.02	.34	4.61	.50	1.12	0	5.0
A2g	1.2	.03	.04	.35	0	.78	0	5.2
Cg1	.8	.03	.05	.26	0	.50	0	5.1
Soil No. 15 Croghan								
H	96.0	.70	2.43	6.86	4.15	6.30	11.17	2.4
A2	1.6	.03	.44	.17	0	1.86	.37	3.6
B21h	10.7	.03	.08	.10	0	7.16	.97	3.8
B22ir	10.3	.03	.02	.09	0	2.69	0	4.3
B23ir	4.4	.02	.01	.10	0	.50	0	4.6
B24	.9	.02	.01	.11	0	.16	0	4.5
B3	1.0	.03	.01	.10	0	.15	0	5.0
C1, C2	.5	.02	.01	.09	0	.22	0	4.8
Soil No. 17 Becket								
H	21.0	.47	.77	4.36	.56	1.38	0	3.9
B2ir	6.0	.02	.07	.23	.05	1.88	0	4.4
B&A	1.5	.09	.04	.29	0	.44	0	5.1
C1x, C2	.7	.11	.04	.21	—	.38	0	5.5

(—) Not analyzed.

Table 5.—*Soil chemical properties (volume basis)*

Horizon	O.M.	Exchangeable cations					
		Na	K	Ca	Mg	Al	H
	g./liter			*meq./liter soil*			
Soil No. 1							
Berkshire							
H	167.3	1.62	3.66	19.59	1.89	11.69	8.05
A2	27.2	.35	.94	3.38	0	25.82	2.73
B21h	122.9	.26	.93	.43	.36	42.59	1.56
B21ir	84.5	.49	.53	.90	.29	—	—
B22	42.4	.43	.24	1.18	0	—	—
A2b	25.9	.39	.21	1.17	0	—	—
B21b, B22b	34.0	.34	.09	1.01	0	—	—
B3b	22.0	.30	.22	.67	0	—	—
C1, C2	11.5	.36	.12	.45	0	—	—
Soil No. 3							
Acton							
H	146.4	1.20	2.87	21.70	3.06	9.96	4.90
A2	8.4	.38	.58	2.39	0	15.75	1.40
B21h, B22ir	14.8	.31	.34	3.48	0	—	—
B23, B24	16.9	.36	.20	.40	0	5.81	0
B3, C	5.6	.18	.10	.39	0	2.49	0
Soil No. 4							
Berkshire							
H	125.6	1.31	3.28	5.70	.83	16.53	12.11
A2	29.5	.38	.67	1.47	.57	20.16	6.60
B21h	190.0	.30	.71	.19	0	—	—
B22ir	101.8	.30	.28	.41	0	10.69	0
B23, B24	31.0	.32	.10	.85	0	5.62	0
B3	33.5	.36	.12	.47	0	5.48	0
C1	22.2	.45	0	.43	0	6.08	0
Soil No. 11							
Undetermined series							
H	20.5	.47	1.01	7.92	1.09	1.73	0
A1	92.5	.07	1.45	19.96	2.18	4.86	0
A2g	18.8	.47	.71	5.69	0	12.52	0
Cgl	12.8	.41	.83	4.21	0	8.30	0
Soil No. 15							
Croghan							
H	64.3	.46	1.58	4.46	2.69	4.10	7.26
A2	18.1	.32	4.87	1.88	0	20.57	4.09
B21h	99.6	.30	.77	.96	0	66.85	9.00
B22ir	124.1	.40	.23	1.05	0	32.51	0
B23ir	60.6	.30	.10	1.32	0	6.79	0
B24	12.1	.31	.13	1.53	0	2.23	0
B3	13.2	.36	.13	1.34	0	2.00	0
C1, C2	7.8	.31	.13	1.20	0	2.82	0
Soil No. 17							
Becket							
H	51.0	1.15	1.87	10.59	1.35	3.36	0
B2ir	57.2	.23	.69	2.16	.45	17.88	0
B&A	20.3	1.26	.50	3.94	—	6.04	0
C1x, C2	101.9	1.52	.57	3.03	—	5.37	0

(—) Not analyzed.

more exchangeable Al in humus (H) than in A2, but in table 5 it is quite clear that the reverse is true. The weight-based figures are misleading because of the large difference in bulk density between these horizons.

Clearly, the expression of milliequivalents on a volume basis has more meaning and therefore greater utility than the expression of milliequivalents on a weight basis. It is hoped that the volume unit will be more widely adopted.

Other important plant nutrients such as N, P, and Mn have not been measured directly in these forest soils, but we do have some knowledge about their availability to trees from the foliar analysis of seedlings growing in the different horizons. In general, humus supplies adequate amounts of N and P, but too much Mn. In contrast, mineral soil horizons[3] are severely deficient in P and N; while Mn was so plentiful as to be toxic in the A2 horizon but merely adequate in the subsoil horizons.

The concentration of each of these three elements is influenced by different factors, so a direct examination of their availability in soils is difficult. This is an area in forest soils research where much more work is needed.

The organic matter in soils play many roles. Organic matter reduces bulk density, improves water-holding capacity, and serves as a reserve store of plant nutrients. Humus is, of course, high in organic matter on a weight basis (table 4)—generally higher than any mineral horizon. However, on a volume basis organic matter may occasionally be higher in some mineral horizons (especially B2h horisons) than in the humus (table 5). This is the result of differences in bulk density.

When the forest cover is reduced by fire, by insects, or by harvesting, the microclimate of the forest floor changes. Generally there is an increase in temperature and a decrease in moisture. As a result of this more favorable environment, microbe activity increases and organic matter is broken down much more rapidly than under a closed canopy. Mineral nutrients are released, and organic N is converted to inorganic N in the forms of ammonium and nitrate, which are then available to plants.

Pioneer plants such as paper birch, pin cherry, and *Rubus* sp., which have a high N requirement, can then become established in the disturbed area as a result of the increased N supply. Shortly thereafter, other woody species like yellow birch, red and sugar maple, and white ash become established beneath the pioneer species and the northern hardwood forest has effectively succeeded itself. *The main ecological key to this succession-in-kind is the release of N stored in the forest floor.*

SUMMARY COMMENTS

The primary parent rock of the forest soils in the White Mountain National Forest in New Hampshire is granite. The profiles have developed in either glacial till or glacial outwash, and are coarse textured, highly acidic, and infertile. All profiles are typically podzol except where gleization has occurred in poorly drained soils. The forest cover is birch-beech-maple, spruce-fir, or an admixture.

The forest floor is composed of litter, fermented, and humus layers. The humus is classified as mor. Under proper conditions of

Table 6. — *Chemical analyses of two additional podzol profiles*

Horizon	Exchangeable cations				
	K	Mg	Ca	Al	H
	meq./liter soil				
Soil No. 21 Hermon (well drained)					
H	2.87	5.75	23.27	11.47	2.99
A2	1.00	0	5.63	13.09	4.75
B22	.52	.72	0	15.12	0
B23	.28	1.25	0	4.22	0
B3	.61	0	0	5.52	0
C	.84	0	0	4.72	0
Soil No. 24 Whitman (poorly drained)					
H	2.49	3.78	25.53	3.55	0
A	1.50	2.89	19.62	4.03	0
G	2.68	.70	4.71	2.27	0

[3]These determinations have been made only with soil no. 21 (table 6), but the chemical analyses of the various soils are so similar that the results should apply quite well to all.

moisture and temperature, large stores of N are released (by mineralization) from the humus. As a result of nutrient cycling, humus is also enriched (relative to the mineral horizons) in cations, especially Ca. *Consequently, humus is the main source of nutrients for the forest vegetation.*

Horizons of the mineral soil have good physical properties of bulk density (except where hardpan or iron pan has developed), moisture-holding capacity, and porosity or aeration. But the levels of plant nutrients are very low in most cases. Available P is critically low (for tree growth) because total P is low and much of it is tied up with Fe and Al under the existing acidic conditions. *The available cations necessary for plant growth* (K, Mg, and Ca) *are critically low in subsoil horizons, especially Ca and Mg.* Not only is the parent rock low in total content of these two elements, but there is little cation-exchange capacity (little or no clay) to retain these cations against severe leaching from a high monthly rainfall.

As a consequence of low Ca and high Al, *there is very little root development below the A horizon.* This is especially true for hardwood species, and blowdowns are common, as the mound and depression topography shows.

I have shown how these soils are able to sustain the forest vegetation, *but it should be understood that being sustained is a long way from being healthy.* The "cure" (as indicated by research) is forest fertilization. Fortunately these sandy forest soils are quite responsive (relative to growth and vigor of the forest vegetation) to the addition of nutrient elements. Maybe someday the wastes of our cities will be used to supply these nutrients, and we will have both healthier cities and healthier forests!

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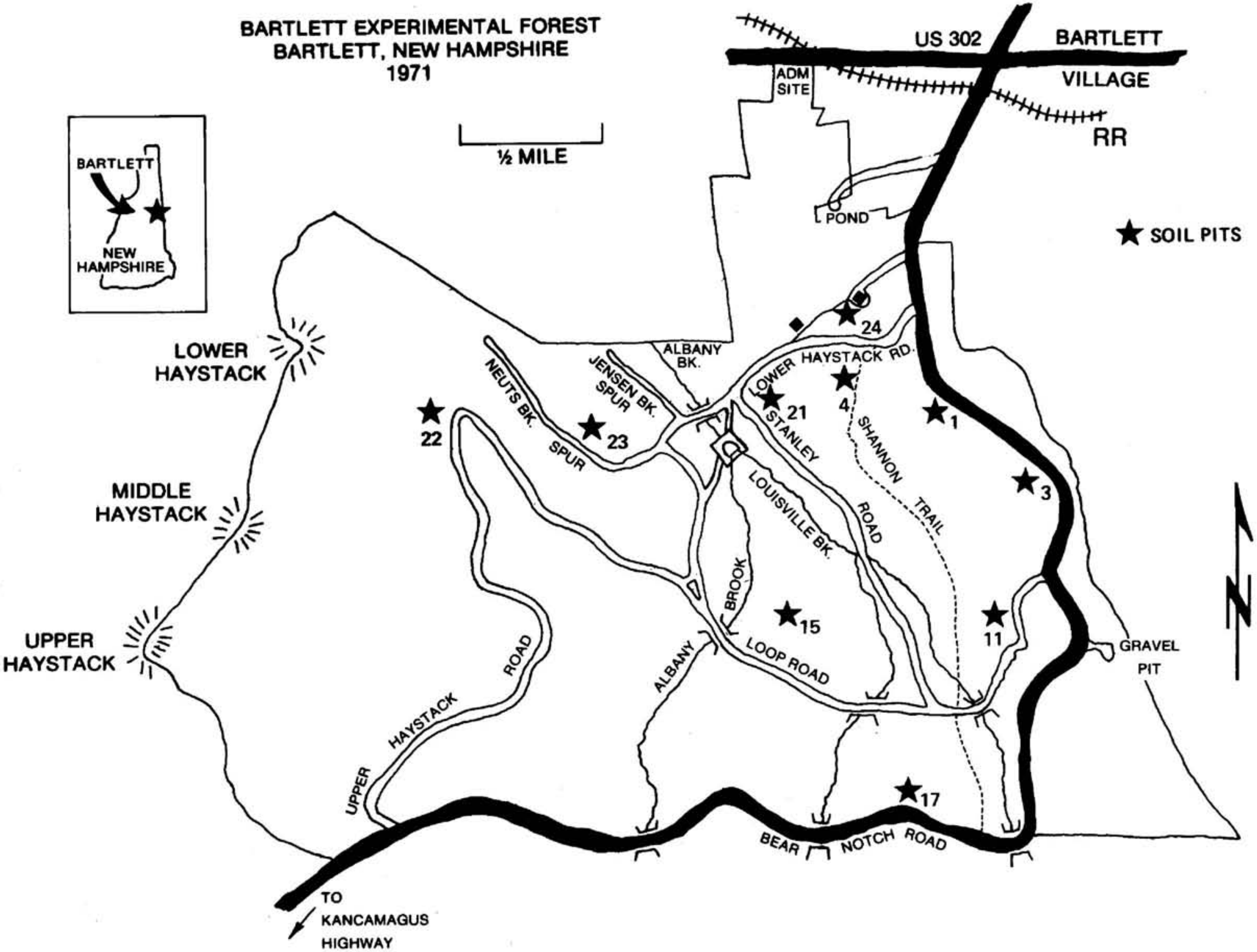
APPENDIX



Map of Bartlett Experimental Forest showing location of soil pits.

Classification and Description of Soils

SOIL NUMBER 1

1. *Miscellaneous Plot Data*

a. Location	Bartlett Experimental Forest, Compartment 14
b. Slope	15 percent
c. Aspect	N 80°E
d. Elevation	940 feet
e. Landform	Gently rolling to steep and hilly uplands of the White Mountains
f. Parent material	Moderately coarse textured glacial till of late Wisconsin age

2. *Soil Classification*

a. Placement in New Soil Classification System:	
(1) Subgroup	Typic Haplorthods
(2) Family	Coarse loamy, mixed, frigid
(3) Series	Berkshire
b. Placement in 1938 Soil Classification System: Podzol	
c. Drainage class	Well drained

3. *Soil Description*

Berkshire very stony fine sandy loam—buried solum variant (all colors for moist soil)

Horizon	*Depth (inches)*	*Description*
01	1.5-1.0	Loose leaf litter
02	1.0-0	Black (N 2/) humus
A2	0-1	Gray (10YR 6/1) fine sandy loam; structure weak, fine granular*
B21h	1-2	Dark reddish brown (5YR 2/2) loamy fine sand
B21ir	2-4	Yellowish red (5YR 4/6) fine sandy loam
B22	4-16	Yellowish brown (10YR 5/6) loamy fine sand
A2h	16-18	Gray (10YR 6/1) fine sandy loam
B21b	18-22	Strong brown (7.5YR 5/6) fine sandy loam
B22b	22-27	Dark yellowish brown (10YR 4/4) fine sandy loam
B3b	27-34	Matrix light olive brown (2.5Y 5/4) loamy fine sand, with few fine distinct strong brown (7.5YR 5/8) mottles, massive
C1	34-41	Matrix light brownish gray (2.5Y 6/2) fine sandy loam, massive
C2	41-46	Matrix light brownish gray (2.5Y 6/2) fine sandy loam, with many medium distinct yellowish red (5YR 5/8) mottles, massive

4. *Remarks*
   a. The profile described is on a tree throw mound. The morphology and horizon sequence of this pedon may be representative of other Berkshire pedons that have had windthrow activity
   b. Weighted average texture of the 10- to 40-inch control section is coarse loamy textural family
   c. Profile description by Pilgrim, Viera and Reiske

*Unless noted otherwise, all other horizons in these descriptions are weak, fine granular in structure.

SOIL NUMBER 3

1. *Miscellaneous Plot Data*

a. Location	Bartlett Experimental Forest, Compartment 15
b. Slope	10 percent
c. Aspect	N 30° E
d. Elevation	1,000 feet
e. Landform	Gently rolling to steep and hilly uplands of the White Mountains
f. Parent material	Moderately coarse textured glacial till of late Wisconsin age

2. *Soil Classification*

a. Placement in New Soil Classification System:

(1) Subgroup	Aquic Entic Haplorthods[4a]
(2) Family	Sandy, siliceous, mesic[4b]
(3) Series	Acton

b. Placement in 1938 Soil Classification System: Brown Podzolic

c. Drainage class — Moderately well drained

3. *Soil Description*

Acton very stony fine sandy loam (all colors for moist soil)

Horizon	*Depth (inches)*	*Description*
01	1.5-1.0	Loose leaf litter
02	1.0-0	Black (10YR 2/1) humus
A2	0-2	Gray (10YR 6/1) fine sandy loam
B21h	2-3	Black (5YR 2/1) fine sandy loam
B22ir	3-6	Yellowish red (5YR 4/6) loamy fine sand
B23	6-17	Yellowish brown (10YR 4/4) loamy fine sand
B24	17-25	Matrix light olive brown (2.5Y 5/4) gravelly loamy fine sand, few fine distinct strong brown (7.5YR 5/6) mottles in lower part of horizon, weak medium subangular, blocky
B3	25-28	Matric light olive brown (2.5Y 5/4) gravelly loamy fine sand with many fine and medium distinct strong brown (7.5YR 5/6) mottles, massive
C	24-44	Matrix light brownish gray (2.5Y 6/2) gravelly loamy fine sand with common medium distinct strong brown (7.5YR 5/6) mottles, massive

4. *Remarks*

a. The organic matter content of the spodic horizon does not meet the definitive limits (over 2 percent organic matter) for Aquic Haplorthods

b. The organic matter content of the spodic horizon places this pedon in the Acton Series and also in the mesic soil temperature class. Pedons of the Waumbek series appear to be more prevalent in the Bartlett Experimental Forest; they belong to the frigid soil temperature class.

c. Profile described by Pilgrim, Viera and Reiske

SOIL NUMBER 4

1. *Miscellaneous Plot Data*

a. Location	Bartlett Experimental Forest Compartment 18
b. Slope	12 percent
c. Aspect	N 5°W
d. Elevation	870 feet
e. Landform	Gently rolling to steep and hilly uplands of the White Mountains
f. Parent material	Moderately coarse textured glacial till of late Wisconsin age

2. *Soil Classification*
   a. Placement in New Soil Classification System
      (1) Subgroup — Typic Haplorthods
      (2) Family — Coarse loamy, mixed, frigid
      (3) Series — Berkshire
   b. Placement in 1938 Soil Classification System: Podzol
   c. Drainage class — Well drained

3. *Soil Description*
   Berkshire very stony fine sandy loam (all colors for moist soil)

Horizon	*Depth (inches)*	*Description*
01	3-2.5	Loose leaf litter
02	2.5-0	Black (10YR 2/1) humus
A2	0-2	Light brownish gray (10YR 6/2) fine sandy loam
B21h	2-3	Black (5YR 2/1) loamy fine sand
B22ir	3-5	Dark red (2.5YR 3/6) loamy fine sand
B23	5-9	Strong brown (7.5YR 5/6) loamy fine sand
B24	9-13	Yellowish brown (10YR 5/6) loamy fine sand
B3	13-24	Light yellowish brown (2.5Y 6/4) fine sandy loam
C1	24-44	Light brownish gray (2.5Y 6/2) and light yellowish brown (2.5Y 6/4) gravelly fine sandy loam, massive
C2	44-48	Light brownish gray (2.5Y 6/2) gravelly fine sandy loam, massive

4. *Remarks*
   a. Profile described by Pilgrim, Viera and Reiske

SOIL NUMBER 11

Note: Because of the high water table, this soil profile was not observed throughout the 40-inch control section. Therefore, no *firm* classification can be given for this soil.

1. *Miscellaneous Plot Data*
   a. Location — Bartlett Experimental Forest, Compartment 16
   b. Slope — 10 percent
   c. Aspect — N 30°W
   d. Elevation — 1,050 feet
   e. Landform — Depressions in the gently rolling to hilly uplands of the White Mountains
   f. Parent material — Not determined

2. *Soil Classification*
   a. Placement in New Soil Classification System: not determined
   b. Placement in 1938 Soil Classification System: Probably Low Humic Gley
   c. Drainage class — Poorly drained

3. *Soil Description* (All colors for moist soil)

Horizon	*Depth (inches)*	*Description*
01	3.5-3	Loose leaf litter
02	3-0	Very dark brown (10YR 2/2) humus
A2g	0-8	Olive gray (5Y 5/2) sandy loam
Bg	8-18	Mottled gray (5Y 5/1), light olive brown (2.5Y 5/4) and brownish yellow (10YR 6/8) loamy sand, massive

4. *Remarks*
   a. Water table at 18 inches
   b. Parent material appears to be water-soaked glacial till
   c. Profile described by Pilgrim and Reiske

SOIL NUMBER 15

1. *Miscellaneous Plot Data*

a. Location	Bartlett Experimental Forest, on the boundary of Compartments 25 and 26.
b. Slope	3 percent
c. Aspect	Flat
d. Elevation	1,000 feet
e. Landform	Nearly level to gently sloping glaciofluvial deposits in the upland areas of the White Mountains
f. Parent material	Coarse textured glaciofluvial material of late Wisconsin age

2. *Soil Classification*
   a. Placement in New Soil Classification System
      (1) Subgroup — Aquic Haplorthods
      (2) Family — Sandy, siliceous, frigid
      (3) Series — Croghan
   b. Placement in 1938 Soil Classification System: Podzol
   c. Drainage class — Moderately well drained

3. *Soil Description*
   Croghan loamy fine sand (all colors for moist soil)

Horizon	*Depth (inches)*	*Description*
011	14-13	Loose litter
012	13-12	Black (5YR 2/1)
021	12-5	Very dusky red (2.5YR 2/2) humus
022	5-0	Black (N 2/) humus
A2	0-3	Brown (7.5YR 5/2) loamy fine sand
B21h	3-5	Black (N 2/) medium sand
B22ir	5-8	Dark reddish brown (2.5YR 3/4) and red (2.5YR 4/6) medium sand
B23ir	8-17	Yellowish red (5YR 4/6) and strong brown (7.5YR 5/6) fine sand
B24	17-29	Brownish yellow (10YR 6/6) medium sand, with few medium distinct (10YR 7/1) mottles, single grain, loose
B3	29-36	Matrix light yellowish brown (2.5Y 6/4) loamy fine sand with common medium faint light brownish gray (2.5Y 6/2) mottles
C1	36-40	Mottled light gray (10YR 7/2) and reddish yellow (7.5YR 6/6-6/8) medium sand, single grain
C2	40-45	Matrix light yellowish brown (2.5Y 6/4) and light brownish gray (2.5Y 6/2) loamy sand, with streaks of reddish yellow (7.5YR 6/8), massive

4. *Remarks*
   a. The total thickness of the 01 and 02 horizons of this pedon may not be representative for the Croghan series in New Hampshire. A thickness of 2 to 6 inches is probably more typical.
   b. Profile description by Pilgrim, Viera, and Reiske

SOIL NUMBER 17

1. *Miscellaneous Plot Data*

a. Location	Bartlett Experimental Forest, Compartment 22
b. Slope	20 percent
c. Aspect	N 60°E
d. Elevation	1,300 feet
e. Landform	Moderately sloping to hilly uplands of the White Mountains
f. Parent material	Moderately coarse textured glacial till of late Wisconsin age

2. *Soil Classification*
   - a. Placement in New Soil Classification System
     - (1) Subgroup — Typic Fragiorthods
     - (2) Family — Sandy, mixed, frigid[4b]
     - (3) Series — Becket
   - b. Placement in 1938 Soil Classification System: Podzol
   - c. Drainage class — Well to moderately well drained

3. *Soil Description*

Becket extremely stony sandy loam (all colors for moist soil)

Horizon	*Depth (inches)*	*Description*
011	1-.5	Loose leaf litter
012	.5-0	Black (10YR 2/1) humus
B2ir	0-2	Dark reddish brown (5YR 3/2) sandy loam
B&A	2-24	Yellowish brown (10YR 5/6) and 10YR 5/8) and dark brown (10YR 4/3) loamy sand
C1x	24-37	Mottled gray (10YR 6/1), dark brown (7.5YR 4/4) and light brownish gray (2.5Y 6/2) loamy sand, weak medium platy structure
C2	37-47	Matrix grayish brown (2.5Y 5/2) loamy sand with common fine and medium distinct strong brown (7.5YR 5/6) and dark brown (7.5YR 4/4) mottles, massive

4. *Remarks*
   - a. The profile described is on a tree throw mound which is typical of microrelief in this area. The B&A horizon represents a mixing of the B and the A horizons.
   - b. The May 1965 placement of Becket is in the coarse loamy textural family.
   - c. Profile described by Pilgrim, Viera and Reiske

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