Journal of the Minnesota Academy of Science

Volume 6 | Number 1 Article 12

4-1938

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CHARACTERISTICS OF SOME FOREST SOILS DEVELOPED ON THE YOUNG RED (PATRICIAN) DRIFT[1]

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Soil formation is the result of a series of reactions, the most important of which we ordinarily include under the broad term of weathering. They include the physical, chemical and biological reactions which are responsible for the breaking down or weathering of rocks and minerals and the creation, accumulation and destruction of organic matter. Besides these there are a number of agencies which have an indirect effect on soil formation. These include the type of parent material, the topography and the age of the land. The texture of the parent material determines primarily the mechanical composition or texture of the soil formed. Sandy soils will develop on sandy parent materials while finer textured soils will form on materials which, upon weathering, yield clays.

The amount and distribution of precipitation along with temperature will, to a large degree, determine the character and rapidity of the soil forming processes. The climate then becomes the controlling factor and while the parent material may impose some restriction on these processes the genetic kind of soil arising under any given set of climatic conditions will be the same regardless of the parent material when the time interval is sufficiently long and the climatic conditions relatively constant.

Of the climatic factors, moisture and its movement through the soil is one of the most important. Whenever the downward movement of water (leaching) exceeds the upward movement (evaporation and transpiration) the soluble products of weathering are leached downward and there tends to be a similar downward movement of colloidal material. This movement tends to impoverish the surface layer and enrich the subsurface in certain constituents since changes in reaction and physical properties of the subsurface layer either stop or delay the transported materials. Thus two layers of horizons are formed — a zone of eluviation or removal at the top and a zone of illuviation or concentration below. Underneath the latter is the unmodified or only slightly modified parent material. This means then that we have three horizons in the soil profile and these have been designated the A, B and C horizons.

[1] Contribution from the Division of Soils and published with the approval of the Director of the Minnesota Agricultural Experiment Station as paper 1648 of the Journal Series.

The present study deals with soils formed on glacial drift laid down during the middle part of the Wisconsin stage of glaciation which has been designated as the young red or Patrician drift. The climate has been such that a forest vegetation has prevailed and the soils formed are strong podzols. This group of soils is characterized by a strongly leached A horizon which, in the lower part or A_2 subhorizon have a light gray or ashy gray color. The iron and alumina have been leached to a large extent and redeposited in the B horizon immediately below, leaving a highly acid, siliceous residue in the A horizon. In most cases the podzols developed on the

TABLE I

HORIZON	MILACA VERY FINE SANDY LOAM		ASKOV VERY FINE SANDY LOAM		CLOQUET VERY FINE SANDY LOAM	
	Depth Inches	Description	Depth Inches	Description	Depth Inches	Description
A_0	2	Forest floor	3	Forest floor	2½	Forest floor
A_1	0–½	Black very fine sandy loam	0–½	Black very fine sandy loam	0–½	Black very fine sandy loam
A_2	½–4	Light gray very fine sandy loam; slightly laminated	½–2	Light gray very fine sandy loam; laminated	½–2	Light gray very fine sandy loam; without structure
A_3	4–9	Yellowish gray very fine sandy loam; slightly laminated; vesicular	2–6	Yellowish brown very fine sandy loam; slightly laminated; vesicular	2–7	Yellowish brown very fine sandy loam; structureless
B_1	9–12	Light brown silt loam; slightly blocky; compact	6–12	Yellowish brown very fine sandy loam; slightly blocky; compact sandstone cobbles	7–12	Yellowish brown very fine sandy loam; structureless; slightly compact
B_2	12–16	Reddish brown sandy clay; slightly blocky; dense and somewhat indurated	12–23	Brownish gray fine sandy loam. Mottled with reddish brown; structureless; somewhat indurated; sandstone cobbles	12–18	Brownish gray fine sandy loam; structureless; somewhat indurated when dry
C	16+	Brick red sandy clay without structure	23+	Brick red sandy clay with pinkish tinge; structureless; sandstone cobbles	18+	Loose dark reddish sand and gravel
Topography		Gently rolling		Gently rolling		Strongly rolling choppy (Sandy moraines)

Patrician drift in Minnesota do not have the characteristic light gray color throughout the A_2 horizon but shade from light gray at the top to a yellowish brown or tan in the lower part. The other morphological features are the same as those of the ordinary podzol. We have designated this tan layer as the A_3 horizon.

The samples selected for study were collected in northern Pine County where the drift left by the Patrician is a stony, coarse textured material of reddish brown color. Three soil types, Milaca very fine sandy loam, Askov very fine sandy loam, and Cloquet very fine sandy loam were sampled. The profile and morphological characteristics are given in Table 1. In general the Milaca and Askov differs from the Cloquet in that they carry a larger number of sandstone

TABLE II. MOISTURE EQUIVALENTS AND pH OF MILACA, ASKOV AND CLOQUET VERY FINE SANDY LOAM

Horizon	Moisture Equivalents			H-ion Concentration — pH		
	Milaca	Askov	Cloquet	Milaca	Askov	Cloquet
A_2	19.3	17.4	18.3	4.7	4.8	4.8
A_3	17.3	13.5	16.0	5.0	4.9	5.2
B_1	17.1	12.1	17.0	4.8	5.2	5.0
B_2	12.8	11.7	10.7	5.1	5.4	5.3
C	10.4	7.8	6.2	5.3	5.5	5.7

pebbles, cobbles and boulders both on the surface and throughout the profile. The topography for both is undulating to gently rolling.

The Cloquet series has developed on sandy moraines where the topography is strongly rolling to rough and where there are many small and rather deep depressions containing water or peat. Its surface relief may be described as "choppy." The parent material of the Cloquet was more coarse and loose than that of the Milaca and Askov.

The natural vegetation now occupying the Milaca and Askov consists of mixed hardwoods with aspen and birch predominating. That on the Cloquet is generally of the same type but also contains some pine.

Samples of soil collected from representative profiles, after the horizon boundaries had been determined as nearly as possible from a field examination, were analyzed for texture, reaction, total nitrogen, total phosphorus, soluble iron and replaceable bases. Determinations on the A_1 horizon were omitted since it was too thin for accurate sampling, the thickness usually being less than one-half inch.

The texture of the profile samples as expressed by the moisture equivalents is shown in Table 2. Of the three types the Milaca is slightly the finer and more uniform in texture. The variation in moisture equivalents is from 19.3 in the A_2 to 10.4 in the C horizon.

The Askov and Cloquet are only very slightly coarser in the A_2 subhorizon having moisture equivalents 17.4 and 18.3 respectively. Both have a coarser texture in C horizon than the Milaca, the moisture equivalents dropping to 7.8 and 6.2.

The determination of the hydrogen-ion concentration showed all samples, regardless of their position in the profile, to be acid in reaction (Table 2). The pH values are lowest for the samples from the A_2 horizon and rise somewhat with depth, each succeeding horizon being less acid than the overlying one. On the average the Milaca profile is slightly more acid than either the Askov or Cloquet, the variation in pH being from 4.7 in the A_2 to 5.3 in the C horizon. There is little difference between the Askov and Cloquet. The high acidity is characteristic of strongly leached profiles and indicates a high degree of unsaturation.

The percentages of total nitrogen are very low for all three types (Table 3). As would be expected they are the highest in the upper part of the A and decrease steadily to the C horizon, where the values were extremely low. In the case of the Askov very fine sandy loam less than .005 per cent was found.

The total P_2O_5 found in the three soil types was also very low (Table 3). When the entire profile is considered the Cloquet is highest and the Askov the lowest in this constituent. The tendency was for the lowest amounts to occur at the surface and to rise very slightly with depth. The variation is between .06 per cent in the A_2 to .08 per cent in the C horizon.

TABLE III. TOTAL NITROGEN AND PHOSPHORUS (P_2O_5) IN THE MILACA, ASKOV AND CLOQUET VERY FINE SANDY LOAMS

Horizon	Total N in Per Cent			Total P_2O_5 in Per Cent		
	Milaca	Askov	Cloquet	Milaca	Askov	Cloquet
A_2	0.07	0.05	0.06	0.06	0.06	0.06
A_3	0.03	0.05	0.04	0.05	0.06	0.09
B_1	0.02	0.03	0.01	0.06	0.05	0.08
B_2	0.02	0.03	0.01	0.07	0.05	0.07
C	0.02	0.00	0.01	0.08	0.06	0.08

The action of physical, chemical and biological weathering reduces mineral particles in size until eventually some of them pass into the colloidal state. These colloids display the usual properties of colloids and have an important bearing on such properties of the soil as water-holding capacity, reaction, fertility and the retention of plant nutrients. One of the most important properties of soil colloids is that of adsorption. They carry a negative charge so are able to hold certain positively charged ions. While all sorts of ions may be adsorbed H, Ca, and Mg are the prominent ones with lesser amounts of K and Na. The adsorbed ions are readily displaced whenever there is a change in the ionic concentration of the soil solution and such an exchange is referred to as ionic exchange or more commonly as base exchange. In the laboratory the replaceable bases may be removed from the soil by treating it with normal ammonium acetate.

The exchange capacity or total exchangeable bases is low in the three soil types studied. This is quite characteristic of podzols. The Milaca very fine sandy loam carries higher amounts on the average than either the Askov or Cloquet. The latter carries the smallest amounts.

Exchangeable hydrogen is the most prominent ion in the exchange complex (Table 4). It is this ion which, having replaced the calcium accounts for the strongly acid reaction. In general the exchangeable Ca rises or falls as the exchangeable H decreases or increases. The exchangeable Mg tends to remain more constant but even this constituent has been replaced to some extent by hydrogen in some instances. Ordinarily the exchangeable H is highest in the upper horizons and decreases with depth. The opposite is true for exchangeable Ca, the larger amounts being found in the B_2 and C horizons.

The amounts of exchange K and Na are relatively small in general. An exception to this is to be observed in the case of the Cloquet very fine sandy loam where the percentage of exchangeable K is higher than that normally found. The amount of exchangeable K

TABLE IV. REPLACEABLE BASES IN MILACA, ASKOV AND CLOQUET VERY FINE SANDY LOAMS

HORIZON	Exchange Cap. M. E.	Per Cent of Total Replaceable Bases				
		H	Ca	Mg	K	Na
		Milaca very fine sandy loam				
A_2	7.3	70.2	15.1	10.4	3.7	0.6
A_3	5.6	56.5	21.4	17.0	4.1	1.0
B_1	12.5	48.7	23.3	25.6	1.2	1.2
B_2	11.9	44.9	24.7	27.9	1.2	1.3
C	11.6	39.9	27.8	29.7	1.2	1.4
		Askov very fine sandy loam				
A_2	8.3	38.7	42.0	14.8	3.5	1.0
A_3	4.4	49.0	34.4	13.0	2.8	0.8
B_1	3.6	57.8	27.5	11.7	2.3	0.7
B_2	5.3	38.4	44.1	15.5	1.4	0.6
C	7.0	30.5	50.8	15.9	2.3	0.5
		Cloquet very fine sandy loam				
A_2	8.4	36.8	37.4	12.4	11.1	2.3
A_3	5.7	61.2	14.9	10.6	8.9	4.4
B_1	3.7	67.4	14.5	11.1	4.3	2.7
B_2	4.3	51.6	19.3	23.5	3.3	2.3
C	3.8	31.2	40.9	18.6	7.6	1.7

tends to decrease from the surface downward while the opposite is true for exchangeable Na.

Mention has already been made of the yellowish brown or tan color of the A_3 horizon of the podzols developed on the Patrician drift. Oxides of iron in large quantities imparts a red to rusty color but in smaller amounts a yellowish color to the soil. In view of this the samples were subjected to analysis for the more readily

TABLE V. PERCENTAGE OF SOLUBLE IRON IN MILACA, ASKOV AND CLOQUET VERY FINE SANDY LOAMS

Horizon	Milaca	Askov	Cloquet
A_2	1.87	1.33	1.23
A_3	2.15	1.93	2.10
B_1	3.03	1.83	2.18
B_2	3.15	2.03	1.97
C	2.97	2.26	1.87

soluble forms of iron by extracting them with six normal hydrochloric acid. The amounts obtained are shown in Table 5.

It is to be noted that in all cases larger amounts of iron in soluble form were found in the A_3 than in the A_2 horizon. In the B and C horizons the amounts were usually slightly higher. In the Milaca and Cloquet profiles the percentages were slightly lower in the B than in the C horizon but with the Askov the reverse was true.

TABLE VI. PERCENTAGE DISTRIBUTION OF YELLOW AND RED IN MILACA, ASKOV AND CLOQUET FINE SANDY LOAMS

Horizon	Percentage Yellow Color			Percentage Red Color		
	Milaca	Askov	Cloquet	Milaca	Askov	Cloquet
A_2	21.0	13.0	13.0	16.5	11.0	13.0
A_3	29.5	28.0	30.0	24.5	22.5	17.0
B_1	28.0	28.5	31.0	27.0	26.0	18.0
B_2	23.0	24.2	27.0	34.0	31.0	17.0
C	20.5	22.2	23.5	33.0	33.2	25.5

The samples were analyzed for color distribution using standard Munsell disks including black, white, yellow and red. The percentage of yellow and red found is shown in Table 6. The yellow color reaches its maximum in the A_3 horizon or B_1 horizon and then decreases. The distribution of red follows rather closely that of soluble iron. Both determinations indicate that the A_3 horizon has not been completely leached of iron so that it is probable that the yellowish brown color of the subhorizon is due to compounds of this element.