THE SOILS DEVELOPED ON WISCONSIN AND ILLINOIAN-AGE GLACIAL OUTWASH TERRACES ALONG LITTLE BEAVER CREEK AND THE ADJOINING UPPER OHIO VALLEY, COLUMBIANA COUNTY, OHIO

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During the progress of the soil survey in Columbiana County, Ohio, two glacial outwash terrace levels were traced from gravelly kame areas in the Wisconsin and Illinoian glacial till plains (White, 1951) along Little Beaver Creek, to the Ohio River (fig. 1). The lower terrace originates in the Wisconsin till plain and is presumed to be Wisconsin glacial outwash. The higher terrace originates in the Illinoian till plain and is presumed to be Illinoian glacial outwash.

The soils developed on these two terrace levels were found to be similar in lithology but to vary in some morphological properties due to difference in age.

Seven well-drained to somewhat excessively drained soil profiles developed from each age of gravelly glacial outwash were sampled and described to determine the soil morphological properties which are common to each respective age of glacial outwash. The properties of soils from Wisconsin outwash and soils from Illinoian outwash, together with detailed profile description of a modal soil of each age, are given.

Physiography of the Region

Columbiana County is in the Allegheny Plateau. Here the plateau consists of knobs at 1360 to 1447 ft, broad gently sloping ridgetops at 1200 to 1320 ft, and benches and lower ridges at 1080- to 1180-ft elevation. (Wellsville, Ohio, W. Va.-Pa.: Lisbon, Ohio: Columbiana, Ohio-Pa; and Salineville, Ohio; quadrangle maps of the U. S. Geological Survey). The physiography and drainage history are described by Stout and Lamborn (1924, p. 9–45). The northern part has been glaciated by the Illinoian and Wisconsin glaciers and is mapped and described by White (1951). The Wisconsin glacial till is classed as Kent till (White, 1953, 1960).

Both the Illinoian and Wisconsin glacial outwash terraces can be traced from gravelly kames, within the respective areas covered by these till sheets, downstream along Little Beaver Creek into the upper Ohio Valley (fig. 1). Within the till sheet boundaries these kames occur as high as the lower parts of the till plains and the terraces are 50 to 100 ft lower in elevation. Beyond each till sheet boundary respective glacial outwashes drop to lower positions in an inner gorge which is the intrenched portion of Little Beaver and upper Ohio valleys. Here the Illinoian terrace remnants range about 100 to 120 ft, and the Wisconsin terrace remnants about 30 to 75 ft above present drainage.

Little Beaver Creek has three tributaries. The North Fork rises in the northeastern part of the county, flows into Pennsylvania and then back into Ohio at Negley. Middle Fork, which is the main tributary, drains the central part of the county. Only the terraces along Middle Fork will be discussed as they are more continuous than those of the other tributaries, but are otherwise similar.

The Middle Fork tributary in the Wisconsin glacial till plain at Leetonia is at 1000-ft elevation. Little Beaver Creek empties into the Ohio River at Smiths Ferry, Pa. at 656 ft. The gradient ranges from 3 ft per mile upstream to 12 ft per mile near its mouth.

Higher pre-Illinoian terraces occur along Little Beaver Creek and the Ohio Valley south of the Illinoian boundary. The higher of these is at 960 to 1020 ft

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(Lessig, 1961). A lower pre-Illinoian terrace at 860 to 940 ft occurs about 150 to 200 ft above drainage. It is at 860 ft in the Ohio Valley (Lessig, 1959a) (fig. 1).

Soil Profile Study Methods

The soil profiles are described according to the conventions and terminology outlined in the Soil Survey Manual (Soil Survey Staff, 1951) with the following exceptions. Quantities of pebbles are indicated as estimated percentages by volume and they were identified visually, using a hand lens, where such identifica-

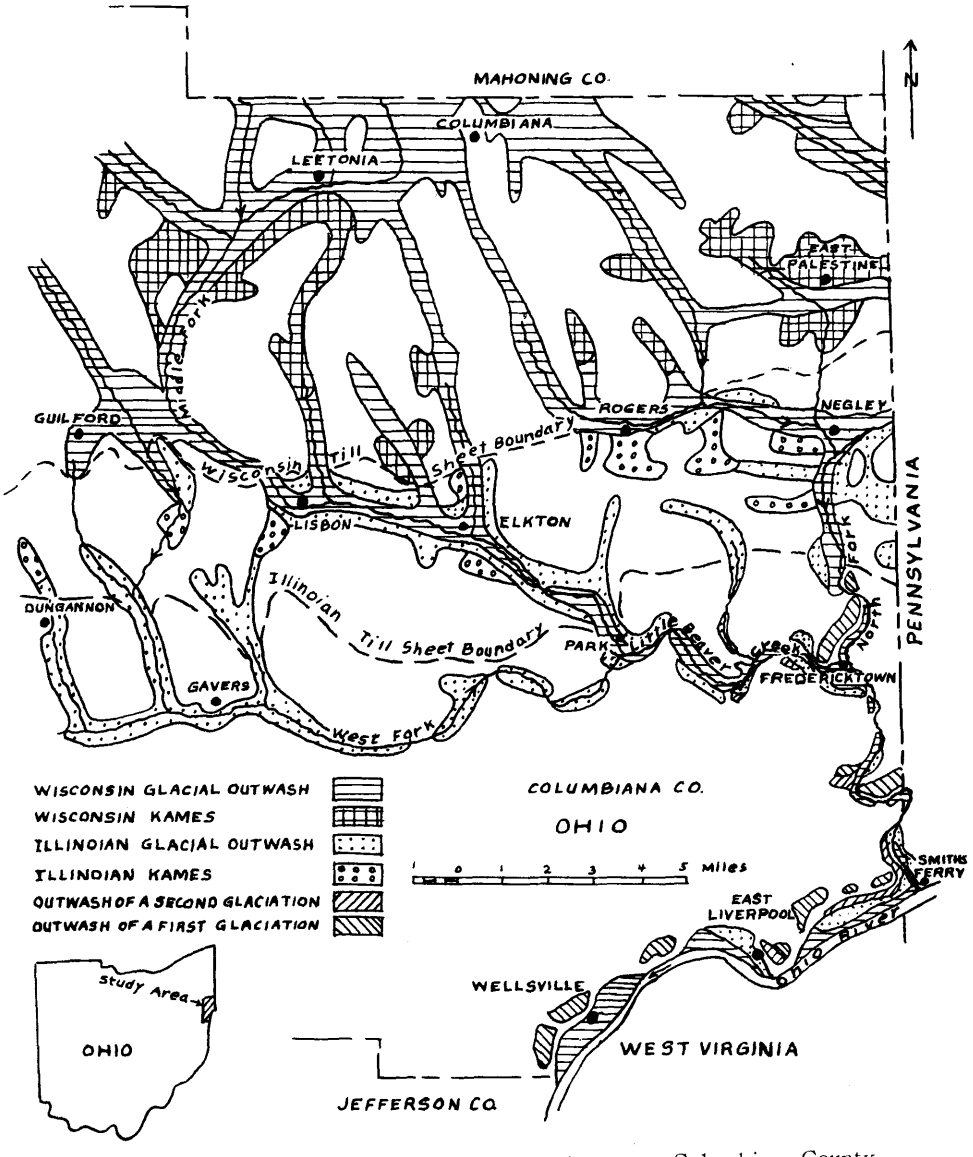

FIGURE 1. Map of glacial outwash terraces in eastern Columbiana County.

tion is given. Coatings and stains on ped faces are described in terms of estimated thickness and texture, and in terms of color according to Munsell notations. Some horizon designations and interpretations are made according to recent definition in "Soil Classification, A Comprehensive System, 7th Approximation" (Soil Survey Staff, 1960). Determinations of pH, made colorimetrically in the field, are given in the profile descriptions, but those reported in table 1, together with data on particle size distribution, are laboratory determinations. Colors and consistence are given for moist conditions. Mechanical analyses were made in the laboratories of The Ohio Agricultural Experiment Station, according to procedure described by Kilmer and Alexander (1949, p. 15–24). Chemical analyses were made in the laboratories of The Ohio Agricultural Experiment Station as follows: exchange acidity was determined by methods of Mehlich (1948). Bases were extracted with normal neutral NH_4Ac (Bray and Willbite, 1929). Potassium was determined by use of Bechman Model DU flame photometer. Calcium and magnesium were determined by EDTA (ethylenediamine-tetra-acetate) photometric titration (Shapiro et al., 1956). Exchange acidity, calcium, magnesium, and potassium were added to obtain the sum of exchangeable cations.

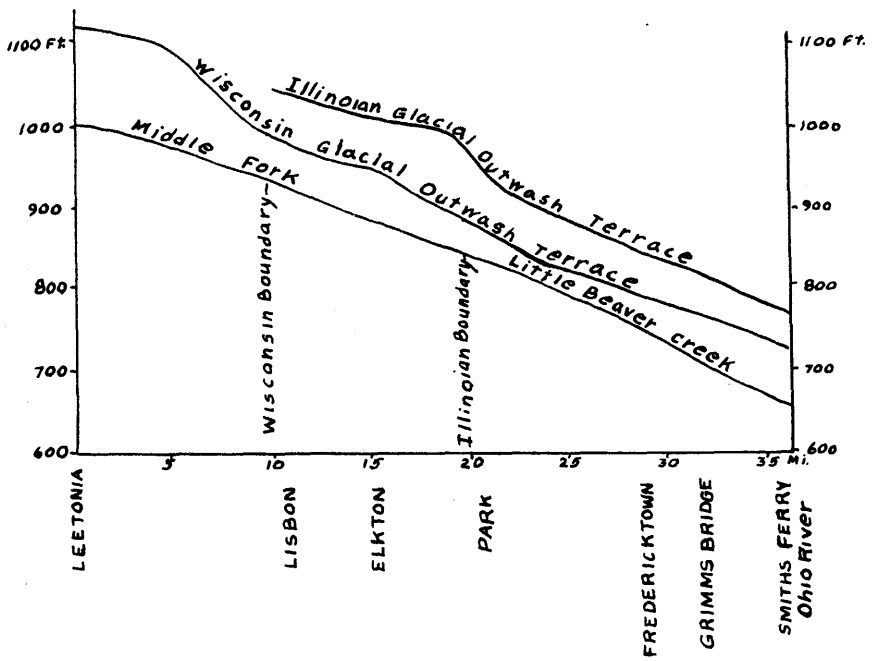

FIGURE 2. Diagram of gradients of Wisconsin and Illinoian-age terraces along Middle Fork and Little Beaver Creek.

Description of the Wisconsin Glacial Outwash Terrace

The Wisconsin glacial outwash terrace is nearly continuous from kames along Little Beaver tributaries, in the Wisconsin glacial till plain to the mouth of Little Beaver Creek at Smiths Ferry (fig. 1). The highest areas of the terrace are at 1180 ft north of Guilford, in the headwaters of West Fork; 1080 ft in the far northeastern part of the county along North Fork; and 1120 ft near Leetonia along Middle Fork. Downstream, the terrace along Middle Fork descends

sharply to 960 ft at the Wisconsin till sheet boundary near Lisbon. It descends rapidly again to 860 ft near the Illinoian till sheet boundary at Park. Downstream it grades to 780 ft at Fredericktown and to 740 ft near the mouth of Little Beaver Creek (fig. 2).

The terrace in the Ohio Valley occurs as remnants on either side of the river. It is at 700- to 720-ft elevation in the east part of East Liverpool and at Wellsville, about 50 ft above river level.

Generally beyond the Wisconsin boundary, the terrace is 40 to 60 ft below the Illinoian terrace. Along Little Beaver Creek it is narrow, ranging from a few hundred to a thousand feet wide, but the terrace in the Ohio Valley is about a half mile wide in some places.

Soil Profiles on the Wisconsin Glacial Outwash Terrace

Soils on the Wisconsin terrace are formed in sandy and gravelly and silty glacial outwash. They are mostly somewhat excessively and well-drained, with silt loam to gravelly loam surface soils and gravelly loam to gravelly sandy loam subsoils. The substratums range from gravelly sandy loam to loamy sand. The solums are moderately deep and leached of carbonates to depths of 6 to 7 ft where the parent materials contain about 5 to 10 percent $CaCO_3$, or equivalent, material.

A modal profile was sampled and described at a point 3 miles east of Lisbon along State Route No. 154, about 400 ft northeast of a junction with a township road in the NE ¼ Sec. 20, Elkrun twp. The site has a 4 percent convex slope and is at 950-ft elevation. Middle Fork, Little Beaver Creek, just below the site, is at 900 ft and the upland is at 1160 ft.

Profile 1.—Description of a somewhat excessively drained soil profile developed from Wisconsin-age gravelly glacial outwash.

Depth and Horizon	Profile Description
0–8 in. A_p	Dark brown (10YR 3/4) gravelly loam; weak very fine angular to subangular blocky structure; friable; pebbles 25%; strongly acid, pH 5.3; boundary clear, smooth.
8–18 in. B_1	Brown (7.5YR 4/4) gravelly sandy loam; weak medium subangular blocky structure; very friable; pebbles 60%; medium acid, pH 5.6; boundary clear, wavy.
18–45 in. B_{21}	Dark brown (7.5YR 4/4) gravelly sandy clay loam to sandy loam; weak medium angular blocky structure; very friable; clay coated pebbles 75%; medium acid, pH 5.8; boundary gradual.
45–60 in. C_1	Dark brown (7.5YR 4/4) gravelly sandy loam; massive; very friable to noncoherent; pebbles 75%, some coated by clay; slightly acid to neutral, pH 6.4 to 7.0; boundary clear, smooth.
60–120 in. C_2	Brown (10YR 4/3) sand and gravel; massive; non-coherent; pebbles 60%; mildly alkaline, pH 7.4; weak effervescence at 70 in., $CaCO_3$ equivalent, 6.9% (lab.); sand and gravel more than 20 ft deep; pebble count at 120 in., 1055 pieces:—41% sandstone, 17% limestone, 12% quartzite, 9% chert, 9% granite, 8% concretions, 4% quartz.

The morphology of this soil shows a textural B horizon, which is evidenced by the clay content of the B_2 horizon at 18 to 45 in. (table 1). However, color and structural development in the B horizons are weak. The profile has a friable consistence. Clay is found as coatings on pebbles and bridges between sand grains to a 53-in. depth. However the clay content of 21% at 23 to 28 in. (table 1) is unusually high for Wisconsin-age gravelly soils. This soil is strongly acid above 45 in. and is leached of carbonates to a 70-in. depth. Pebbles of limestone are not found above 70 in. The pebbles of granite in the solum do not have strongly

weathered rinds. The unweathered outwash at the 120-in. depth contains a high percentage of foreign rocks. In the B horizon, the percentage of base saturation ranges from 19 to 58 percent and the ratio of calcium to magnesium ranges from 1.5 to 6.1 (table 1). The soil profile described is tentatively classed in the Chili series in the Columbiana County soil survey, a Gray-Brown Podsolic soil.

TABLE 1

Laboratory data for Profiles 1 and 2

Depth in inches	Horizon	Particle size distribution (in mm) (percent)				Chemical						
		Sand 2–0.05 mm	Silt 0.05–0.002 mm	Total Clay > .002 mm	Fine Clay > .0002 mm	pH	Exchangeable Cations in mEq./100 gm. H	Ca	Mg	K	Base saturation in percent	Ratio of Ca/Mg
Profile 1—Soil formed from Wisconsin-age gravelly glacial outwash												
0–8	A_p	40	45	15	4	4.9	9.8	1.6	1.5	0.3	26	1.1
8–12	B_1	62	25	13	3	4.8	7.3	1.3	0.2	0.2	19	6.1
12–18	B_1	74	15	11	4	5.0	6.6	2.0	0.6	0.1	26	3.3
18–23	B_2	66	16	18	9	5.1	7.1	3.9	2.7	0.2	49	1.5
23–28	B_2	67	12	21	11	5.1	7.5	4.3	2.7	0.3	49	1.6
28–37	B_2	72	9	19	11	5.1	7.5	3.9	2.1	0.3	46	1.9
37–45	B_2	75	6	19	13	5.4	6.0	5.7	2.4	0.3	58	2.4
45–53	C_1	79	8	13	6	6.0	3.9	3.1	2.4	0.2	59	1.3
53–60	C_1	88	5	7	3	7.3						
65–70	C_2	95	2	3	2	7.6						
Profile 2–Soil formed from Illinoian-age gravelly glacial outwash												
0–1	A_1	52	40	8	2	5.2	22.3	6.3	3.9	0.6	3	1.6
1–9	A_2	31	52	17	3	4.2	8.6	0.6	0.1	0.2	10	6.0
9–11	B_1	37	40	23	7	4.2	10.8	0.3	0.1	0.2	5	3.0
11–17	B_{21}	50	19	31	11	4.2	14.8	0.3	0.7	0.3	8	0.4
17–28	B_{21}	50	17	33	16	4.4	14.4	2.1	1.1	0.4	20	1.9
28–39	B_{22}	63	14	23	9	4.7	10.4	2.1	1.2	0.4	26	1.7
39–72	B_{31}	72	14	14	6	4.7	8.9	1.6	1.0	0.2	24	1.6
72–99	B_{32}	75	11	14	5	4.9	7.9	1.1	2.0	0.1	29	0.5
99–135	C_1	83	9	8	2	4.8	9.4	1.0	2.1	0.1	25	0.5
135–171	C_2	75	11	14	5	6.1	3.7	3.7	1.5	0.1	59	2.5
171–267	C_2	77	9	14	5	6.0	3.4	3.3	2.3	0.1	61	1.5
267–300	C_3	75	11	14	6	7.7						

Six other soils studied and sampled, which are formed in Wisconsin gravelly outwash, have brown to dark brown (10YR hue) A horizons; dark brown (7.5YR hue) textural B horizons with weak structure. The average ratio of percentage clay in B horizons to clay in A horizons of these other profiles is 1.3 (table 3). Only one profile sampled has such a ratio of less than 1.2. These soils are gritty throughout and lack fragipans. Depths to carbonates vary from 5 to 10 ft, according to the amount of pebbles of limestone in the outwash. Sandy horizons tend to be acid even though they are unweathered. Horizons containing a large amount of gravel tend to be more alkaline. Figure 3 is compiled by averaging the pH value at various depths of 10 soils formed in Wisconsin and 14 soils formed in Illinoian gravelly glacial outwash. The Wisconsin soils have an average pH ranging from 5.0 to 5.4 at 10 to 45 in. They are neutral in reaction at the 70-in. depth. Other common morphological properties are given in tables 2 and 3 and are compared below in the section on soil profiles of the Illinoian glacial outwash terrace.

Description of the Illinoian Glacial Outwash Terrace

The Illinoian glacial outwash terrace is continuous along Middle Fork and other tributaries from gravelly kames in the Illinoian glacial till plain to the glacial boundary. Along Middle Fork the general terrace level is at 980- to 1040-ft elevation. It descends sharply to 920 ft into the gorge of Little Beaver Creek at the Illinoian boundary at Park. Downstream the remnants are at 840 ft at Fredericktown and 770 to 740 ft at the mouth of Little Beaver Creek and along the Ohio River at East Liverpool (fig. 2). Generally, it is 40 to 80 ft higher than the Wisconsin terrace and 90 to 120 ft above drainage. Beyond the glacial boundary along Little Beaver Creek it is only a few hundred feet wide but in the Ohio Valley it is a half mile wide.

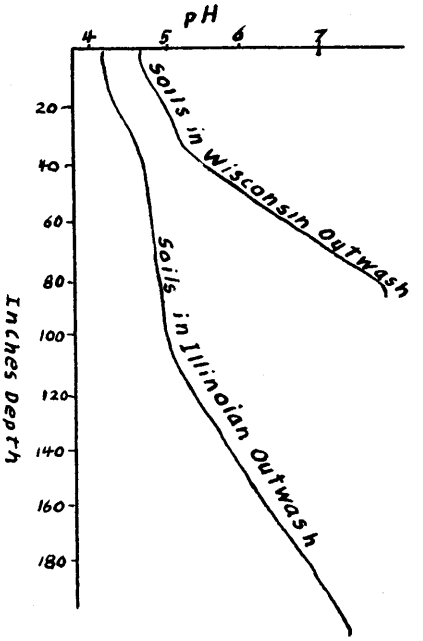

FIGURE 3. Curves showing average pH at various depths of 10 soils formed from Wisconsin-age and 14 soils formed from Illinoian-age glacial outwash in Columbiana County, Ohio.

Soil Profiles on the Illinoian Glacial Outwash Terrace

Soils on the Illinoian terrace are formed in silty to gravelly and sandy glacial outwash which is similar to that of the Wisconsin terrace. However, the upper solums are usually more silty and moderately well-drained soils are more common on the Illinoian terrace, but well to somewhat excessively drained soils predominate. The solums are usually deep and leached to depths of 17 to 20 ft, where the parent materials contain about 5 percent of $CaCO_3$, or equivalent materials.

A modal profile was sampled and described on a kame in the center of the SW¼ of SE¼ of NE¼ Sec. 20, Center Twp. The sample site is in a gently sloping forested area at the crest of an 18 percent slope, at a 1200–ft elevation. The area nearby is presently being strip mined for coal. West Fork Little Beaver Creek is just below at a 1060-ft elevation.

Profile 2.—Description of somewhat excessively drained soil profile developed from Illinoian-age gravelly glacial outwash (described and sampled by W. F. Hale and H. D. Lessig)

Depth and Horizon	Profile Description
0–1 in. A_1	Black (10YR 2/1) gravelly sandy loam; weak very fine granular structure; friable; pebbles 20%; strongly acid, pH 5.2; boundary abrupt, wavy.
1–9 in. A_2	Yellowish brown (10YR 5/4) gravelly silt loam; weak very fine granular structure; friable; pebbles 20%; very strongly acid, pH 4.8; boundary abrupt, smooth.
9–11 in. B_1	Dark yellowish brown (10YR 4/4) gravelly loam; weak fine angular blocky structure; brown (7.5YR 4/4) degraded clay ped faces; friable; pebbles 30%; very strongly acid, pH 4.6; boundary clear, wavy.
11–28 in. B_{21}	Dark brown (7.5YR 4/4) gravelly clay loam to sandy clay loam with common coarse black Mn stains; moderate medium angular to subangular blocky structure; thin reddish brown (5YR 4/4) clay coatings on all pebbles; firm in position but friable when disturbed; pebbles 50%; strongly acid, pH 4.6; boundary gradual.
28–39 in. B_{22}	Brown (7.5YR 4/4) gravelly sandy clay loam; weak medium and fine angular blocky structure; firm in position but friable when disturbed; pebbles 60% with thin reddish brown (5YR 4/4) clay coatings on pebbles; strongly acid, pH 5.2; boundary clear, wavy.
39–72 in. B_{31}	Brown (7.5YR 4/4) gravelly sandy loam; very weak medium and fine angular blocky structure; friable; pebbles 60% with thin clay coatings on pebbles, in pores, and bridging sand grains; strongly acid, pH 5.2; boundary abrupt, smooth.
72–99 in. B_{32}	Dark yellowish brown (10YR 4/4) gravelly sandy loam; weak coarse angular blocky structure; friable; pebbles 30% with thin clay flows on pebbles and bridging sand grains; strongly acid, pH 5.2; boundary abrupt smooth.
99–135 in. C_1	Brown (10YR 5/3) gravelly loamy sand; massive; noncoherent; pebbles 40%; very strongly acid, pH 5.0.
135–267 in. C_2	Brown (10YR 4/3) gravelly sandy loam; massive; noncoherent; pebbles 70%; slightly acid, pH 6.4.
267–300 in. C_3	Dark grayish brown (10YR 4/2) gravelly sandy loam; strong effervescence, pH 7.3; $CaCO_3$ equivalent 2.4% (lab.); pebble count 300-in. depth, 311 pieces:—sandstone 40%, siltstone 11%, limestone 15%, quartzite and quartz 9%, granite 4%, concretions 14%, chert 6%, gneiss and schist 1%.

The morphological properties of this profile are a textural B horizon at 9 to 39 in. (table 1), and a structural and color B horizon at 11 to 99 in. The soil profile at 11 to 39 in. is firm but friable when removed. It is extremely to very strongly acid at the 135-in. depth (table 1), and is leached of carbonates to 267 in. The pebble composition at 300 in. is comparable to that found in the Wisconsin outwash at 120 in. In the B horizon the percentage of base saturation ranges from 5 to 29 percent. The ratio of calcium to magnesium ranges from .4 to 3.0 (table 1). This profile is tentatively classed in the Negley series in the Columbiana County Soil Survey.

Six other soils studied which are formed in Illinoian-age gravelly outwash have brown to dark brown (10YR hue) silt loam surface soils; dark yellowish brown loam to silt loam upper subsoils; and dark brown (7.5YR hue) gravelly sandy clay loam lower subsoils. These subsoils have a moderate grade of structure.

The substratums are brown gravelly sandy loam. The average pH value at various depths of 14 soils formed in Illinoian gravelly outwash ranges from 4.2 to 4.6 at 10- to 45-in. depths. They are neutral in reaction at 190-in. average depth (fig. 3). These solums are less gritty than those of the Wisconsin age outwash and usually have higher amounts of silt in the upper solums. Pebbles of granite in the solums have strongly weathered rinds but are not strongly weathered in their interiors.

Generally soils formed in glacial outwash with a lower percentage of limestone pebbles are more deeply leached and those with a higher percentage of concretions (kidney iron ore) are more reddish. The lithology of gravel in local glacial outwash varies within short distances.

TABLE 2

Average percentages of clay found at various depths in soils formed from Wisconsin-age and Illinoian-age gravelly glacial outwash

Inches in depth	0–8	8–12	12–22	22–30	30–47	47–62	62–92	92–240
Seven Wisconsin-age soils	14	15	16	15	14	11	8	
Seven Illinoian-age soils	17	22	25	23	18	17	13	9

TABLE 3

Average morphological properties of soils developed from Wisconsin-age and Illinoian-age gravelly glacial outwash

	Laboratory pH of B_2 horizon	Depth to carbonates	Depth great decrease in clay content	Greatest depth in soil at which clay coats sand and gravel	Ratio of % clay in B to % clay in A horizon	Depth to which 7.5 YR hue color occurs
Seven Wisconsin-age soils	5.2	84 in.	43 in.	59 in.	1.3	59 in.
Seven Illinoian-age soils	4.6	210 in.	61 in.	100 in.	1.6	90 in.

In table 3 the data show the Illinoian-age soils are 0.6 pH (determined in the laboratory) more strongly acid; 126 in. more deeply leached; have 18-in. thicker zones of increased clay; have clay coatings and bridges on sand and gravel to 41-in. greater depth; and have 4 to 9 percent more clay in the B horizon (table 2) than the Wisconsin-age soils. The average ratio of percentage clay in the B horizon to percentage clay in the A horizon is 1.6 in the Illinoian-age soils as compared to 1.3 in the Wisconsin-age soils. The average percentage base saturation of the B horizon of the Illinoian soil (Profile 2) is 18 as compared to 41 percent in that of the Wisconsin soil (Profile 1). The average ratio of calcium to magnesium is 1.5 in the Illinoian B horizon as compared to 2.8 in the Wisconsin B horizon.

The local soils formed in Wisconsin-age and Illinoian-age glacial tills have similar differences, but they have strong fragipans and higher clay content than the soils formed in outwash.

Discussion

The soil developed from Wisconsin-age gravelly glacial outwash (Profile 1) is not so deep as the soil developed from Illinoian-age gravelly glacial outwash (Profile 2). Profile 1 has significantly smaller amounts of clay, less structure, is more friable, and is less acid than Profile 2. However, these two profiles are developed in parent materials with similar lithology. They have similar colors in the various soil horizons except that comparable horizons are thicker in Profile 2.

These variances are shown in tables 2 and 3, where average morphological properties of 7 soils developed in Wisconsin-age gravelly glacial outwash are compared with 7 soils developed in Illinoian-age gravelly glacial outwash. These differences in averages, discussed under Profile 2, show the same greater degree

of soil formation in Illinoian-age soils than in the Wisconsin-age soils. The thickness of the B_2 horizons, as identified in the field, and the depth in the solums to which 7.5YR hue, dark brown colors are found, is less in the Wisconsin-age soils. The morphological differences between the Wisconsin-age and Illinoian-age soils apparently are a matter of degree rather than quality. The older Illinoian soils have developed over a longer period of time, encompassing the Sangamon interglacial stage, the Wisconsin glacial stage and post-Wisconsin time. They have a greater amount of soil formation. The Illinoian-age soil has a lower base status than the Wisconsin-age soil. It also has a lower calcium content in proportion to the amount of magnesium. These are evidence of a greater amount of leaching due to a longer period of soil formation.

I found no evidence that variations in post-Illinoian climates produced a different kind of soil formation in Profile 2 from that in Profile 1. However, Profile 2 (Illinoian) has less than 35 percent base saturation in the B horizon and, thus, fits Red-Yellow Podsolic soils or Ultisols (Soil Survey Staff, 1960). It lacks the yellowish-red colors which is found in soils formed in pre-Illinoian outwash.

Other soils in the region, which I believe to be formed from pre-Illinoian glacial outwash, have higher chromas in the 5YR hue colors, higher percentages of clay formed in the B horizons, and are leached to greater than 30-ft depths. Some have plinthite. The pebbles of granite in these solums are entirely decomposed or lacking. These soils are interpreted to be Red-Yellow Podsolic soils (Lessig, 1959b, 1961).

Conclusion

The soils developed from Wisconsin-age gravelly glacial outwash along Little Beaver Creek and the upper Ohio Valley have similar profiles to soils developed from Illinoian-age gravelly glacial outwash, but are not as strongly formed and as deeply weathered. The Illinoian-age soils have thicker B horizons, more clay formed, are more acid, more deeply leached, have a lower base status and a lower calcium-magnesium ratio than the Wisconsin-age soils. The Illinoian-age glacial outwash terrace is 40 to 60 ft higher than the Wisconsin-age glacial outwash terrace along Little Beaver Creek. In the upper Ohio Valley the Illinoian terrace is at 740 to 770 ft and the Wisconsin terrace is at 700- to 720-ft elevation. Both these terrace levels are lower and their soils are less deeply formed than those of older and higher glacial outwashes at about 860- and 960-ft elevations in the upper Ohio Valley (fig. 1) described in my earlier reports.

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