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Properties of Soils of the Outwash Terraces of Wisconsin Age in Iowa

By C. LYNN COULTAS[1] AND RALPH J. MCCRACKEN[2]

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INTRODUCTION

For adequate classification and mapping of soils it is necessary to learn as much as possible about their chemical and physical properties, their age, and the parent materials or geological materials from which they have formed. Soil properties which vary with age, texture (the particle size distribution), and lithology have significant bearing, for example, on use and management suggestions, corn suitability ratings, and tax assessment value of soils. Thus it becomes necessary to discriminate age differences and significant textural and lithologic variations in the materials being studied. In the case of most Iowa soils, these problems are held in common with students of Pleistocene geology.

These joint soil-geological problems are especially well demonstrated in the case of soils developed on the Wisconsin outwash terraces in Iowa. In the past, nearly all the well drained soils of these terraces have been classified with the O'Neill soil series. As a result, the O'Neill series, as mapped in the older county soil surveys, extends from Nebraska to Illinois. It has embraced wide ranges in texture, lithology, carbonate content, and in additional properties co-varying with these features.

The aid of Pleistocene geologists is solicited in determining age assignments of the outwash gravel deposits, in determining if significant lithologic variations occur in the various deposits, and in the investigation of size-sorting variations and their significance. Geologic investigations of this nature have been conducted and reported (Kay and Miller, 1941) and are extremely useful. Even more detailed information on the outwash gravel is desirable, however, for satisfactory soil classification.

In this paper, variations in physical and chemical properties of some of the soils on the terraces, as measured in the laboratory, are correlated with observable variations in soil profile characteristics.

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It is hoped that this information, plus additional information from the field of geology, will lead to better understanding of the genesis, morphology and satisfactory correlation of these soils.

PREVIOUS INVESTIGATIONS OF TERRACE GRAVELS IN IOWA

The various county reports of the Iowa Geological Survey describe in some detail sections of terrace gravel and sands of Wisconsin age. Economic aspects of these deposits have been discussed by Beyer (1914) and by Wood (1935) in their reports on road and concrete materials in Iowa.

A comprehensive report on the Pleistocene gravels of Iowa has been presented by Kay and Miller (1941). Wisconsin age terrace and "upland" gravels are differentiated by these authors. The former type, deposited along valleys, is discussed in the present paper, Iowan and Mankato[2] terrace gravels were discriminated by Kay and Miller. They have also described deposits of "undifferentiated terrace gravel" for which age assignments were not made.

Soils developed on these terraces have been described in the county soil survey reports of the Iowa Agricultural Experiment Station and their distribution delineated on maps included with these reports. The soils have generally been classified in one series, the O'Neill series.

DISTRIBUTION OF WISCONSIN TERRACE GRAVELS IN IOWA

Iowan: Terraces which can be identified as being of Iowan age are found along nearly every stream in that region of Iowan glaciation which did not receive appreciable glacial meltwater from the Late Wisconsin glaciations (parts of northeastern and northwestern Iowa, Fig. 1). Where streams heading in the region of Late Wisconsin glaciation flow into the Iowan glaciated regions, terrace gravels of both Early and Late Wisconsin age are found. Where deposits of these glaciations cannot be differentiated, Kay and Miller (op. cit.) have applied the term "undifferentiated terrace gravel." This term is also applied to those areas just outside the Iowan drift region, where Iowan terrace gravel is associated with pre-Wisconsin stratified drift.

Late Wisconsin: Late Wisconsin terraces are found along nearly every stream in the Des Moines lobe of glaciation in north-central Iowa (Fig. 1). They are also found outside the southern periphery

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[2] In the present paper no attempt is made to distinguish between Mankato and Cary outwash, for which the general term "Late Wisconsin" is used. The work of Kay and Miller was conducted before the recent recognition of Cary glaciation in the Des Moines lobe.

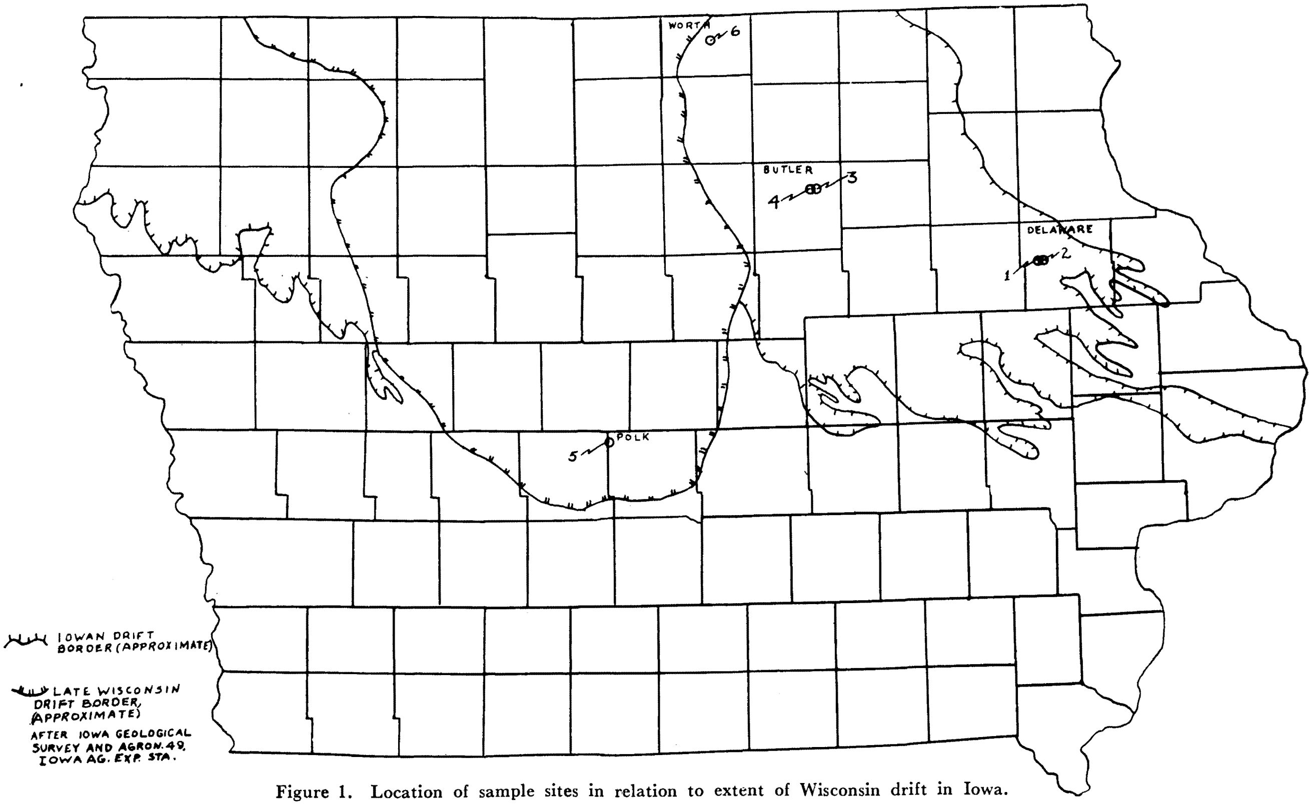

Figure 1. Location of sample sites in relation to extent of Wisconsin drift in Iowa.

Table 1.

Distribution of the O'Neill series in Iowa

				Types in Acres				
County	Loam	Silt loam	Sandy loam	Fine Sandy loam	Coarse Sandy loam	Sand	Loam (deep phase)	Loam (Light-colored phase)
Benton	768		768					
Black Hawk	1,472		6,528		14.784	2,112		
Bremer			8,192		2,944			
Boone	704			1,344				
Buchanan	12,608		4,416	5,952				320
Buena Vista	1,600			320		64		
Butler	16,064		9,664					
Calhoun	704							
Carroll	3,136			1,920				
Cerro Gordo	4,264 (est.)	2,976 (est.)						
Chickasaw	17,152	4,352	11,392					1,600
Clay	29,184			2,048				
Clayton	832		1,920					
Dallas	3,968			1,024				
Delaware	12,544		4,928					
Dickinson	8,640			768				
Dubuque	1,664							
Emmet	768			1,024				
Fayette	14,976		1,664					
Floyd	12,992	9,088	2,560					
Franklin	15,533 (est.)		1,478 (est.)					
Greene	1,024		7,936					
Grundy			1,088					
Guthrie				1,024				
Hancock	12,416							
Hardin	7,872							
Howard	9,920			8,064				
Ida	212 (est.)							
Jasper	192							
Jones	384							
Marion	179 (est.)			90 (est.)				
O'Brien	1,344							
Osceola	5,736 (est.)	2,604 (est.)						
Palo Alto	5,888			6,144				
Plymouth	256		192					
Pocahontas	896			1,536				
Polk	2,048			4,928				
Sac	6,208							
Winneshiek	2,048		1,728	448				
Woodbury	1,600							
Worth	7,616		896				11,456	
Wright	4,608							
Total	230,020	19,020	65,350	36,634	17,728	2,176	11,456	1,920
Grand Total	384,304							

of the Des Moines lobe, along streams heading in the region of Late Wisconsin glaciation.

EXTENT OF SOILS DEVELOPED ON WISCONSIN TERRACES

Extent and distribution of soils developed on outwash terraces in Iowa is shown in the acreage table (Table 1). This summary includes all soils which have been classified in the O'Neill series and therefore includes a few areas of soils of pre-Wisconsin terraces and of soils of terraces undifferentiated as to age. However, the acreages summarized in the table are very dominantly soils developed on terraces of Wisconsin age. The grand total of 384,304 acres (equal to about 600 square miles) indicates the importance of these soils to Iowa agriculture.

GEOLOGIC SECTIONS OF THE TERRACES

Iowan: Typical sections of terraces of Iowan age are described by Kay and Miller (op. cit.) as consisting of overburden, coarse and average gravel, sand and fine gravel—in descending order. The overburden is described as two types: "coarse unstratified sandy silt," or "Peorian loess." No indications of a time interval between the deposition of the gravel and the overburden were found by these investigators. They described the average thickness of the overburden as three feet, though somewhat variable. Average depth of leaching was assumed by Kay and Miller to be about four to six feet, though variable with lithological and post-depositional erosional differences. The gravel is described as dominantly intermediate in carbonate composition, with extremes ranging from completely non-calcareous rather siliceous gravel to highly calcareous gravel. Generally the gravel has thin iron oxide films. These conclusions were drawn from determinations of the lithology of pebbles between 16 and 32 mm. diameter in a number of sections.

Late Wisconsin: The Late Wisconsin terrace sections are described by Kay and Miller as consisting of overburden of unstratified silt underlain at depths from six feet to a few inches below the surface by gravel which is commonly calcareous (overburden may be completely absent). The overburden is described as leached of carbonates. The underlying gravel is described as slightly leached where the overburden is less than about 30 inches thick. Oxidation of the underlying gravel was reported as "slight."

DESCRIPTION OF SOIL PROFILES SAMPLED

Six profile samples of soils developed on the terraces were taken for laboratory analyses in the present study. Descriptions of each of these profiles are presented in the block diagrams of Figure 2. Two

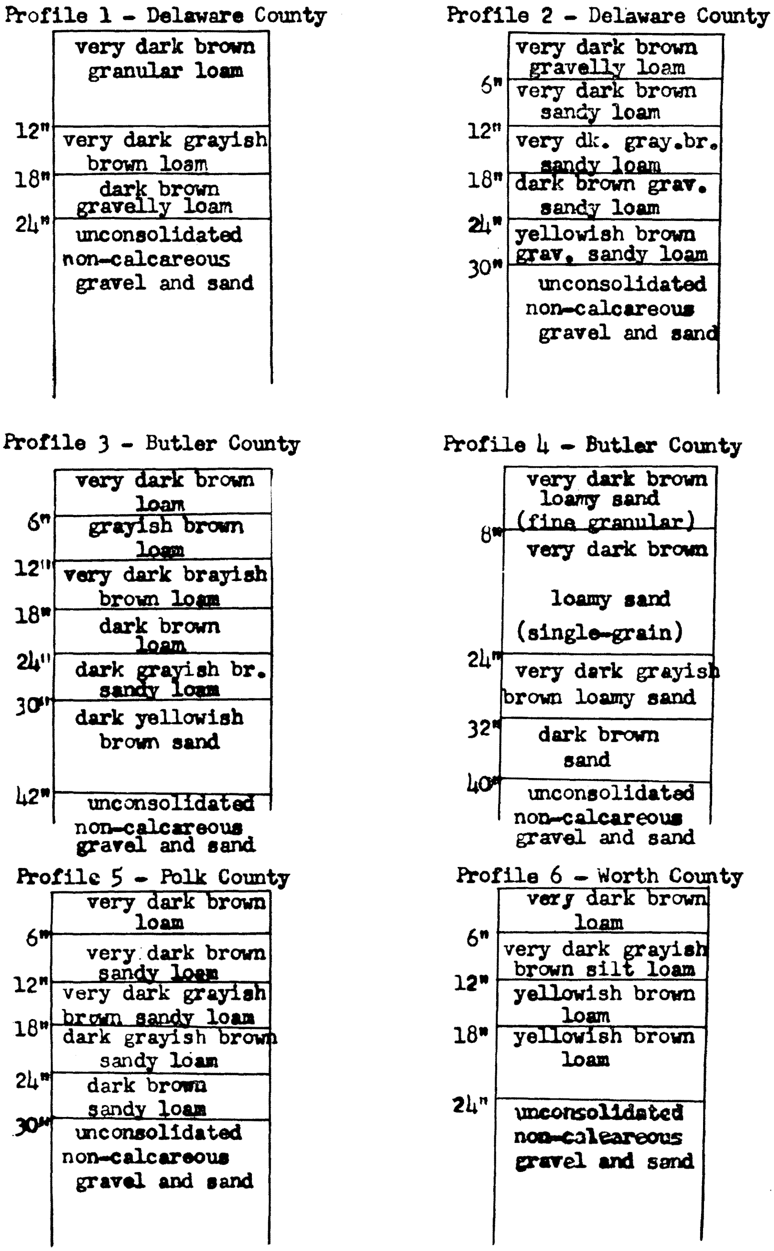

Figure 2. Description of profiles sampled for laboratory analysis.

of these, profiles 1 and 2, were obtained from terraces along streams of the Iowan glaciated region which head within the Iowan till plain. The remaining four samples (profiles 3, 4, 5 and 6) were taken from terraces along streams heading within the Des Moines lobe. Locations of these samples are indicated by the numbers in Figure 1, which correspond to the soil profile numbers. Exact locations of each of the sample sites are given in the Appendix.

These profiles are all within the range of soil properties which have formerly been classified with the O'Neill series. All may be classified in the Brunigra (Prairie) great soil group, developed under grass vegetation. The A and B horizons have, for the most part, developed in the material Kay and Miller (op. cit.) term the "silty overburden."

Analyses of the Soil Profiles

Methods of Investigation: All particle size distribution determinations (mechanical analyses) and exchangeable base determinations were made on the fraction of the samples passing through a two-millimeter sieve. The pipette method was used for determining particle size distribution. Porosity and bulk density determinations were made on core samples. Complete descriptions of method used are presented elsewhere by the senior author (Coultas, 1951).

Particle Size Distribution: Particle size distribution varied widely between some of the profiles sampled, as shown in Figure 3. Pro-

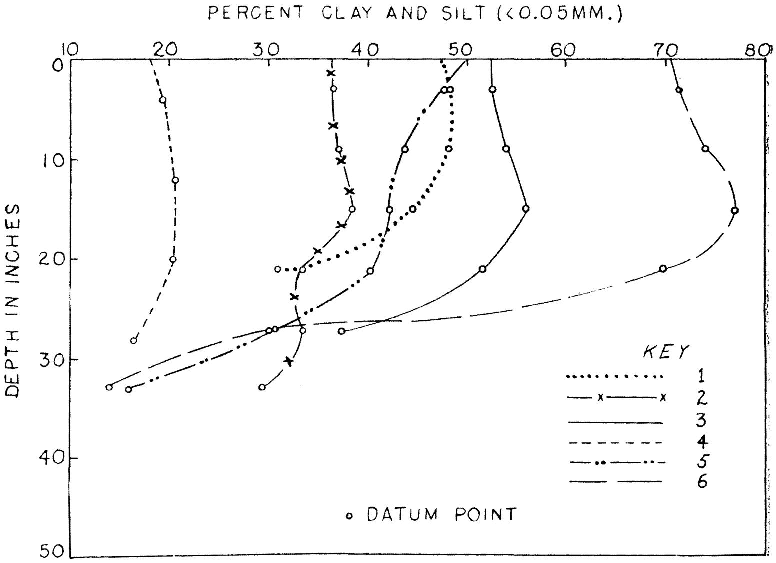

Figure 3. Percent clay and silt with increasing depth in the profiles.

file 6 is the highest in clay plus silt, ranging from 70 to 77 percent clay plus silt, having about 19 to 21 percent in the upper 20 inches. The remaining profiles are intermediate in clay plus silt.

The variation in percent of clay particles less than two microns in diameter with increasing depth in the profile (Fig. 4) is rather uniform throughout all profiles sampled. A slight "bowing out" of some of these clay distribution curves may indicate some clay accumulation in the B horizon. Profile 6 is highest in clay content, profile 4 the lowest.

The sand fraction (particles larger than 0.05 mm. in diameter) is fairly uniformly distributed throughout the upper 18 inches of

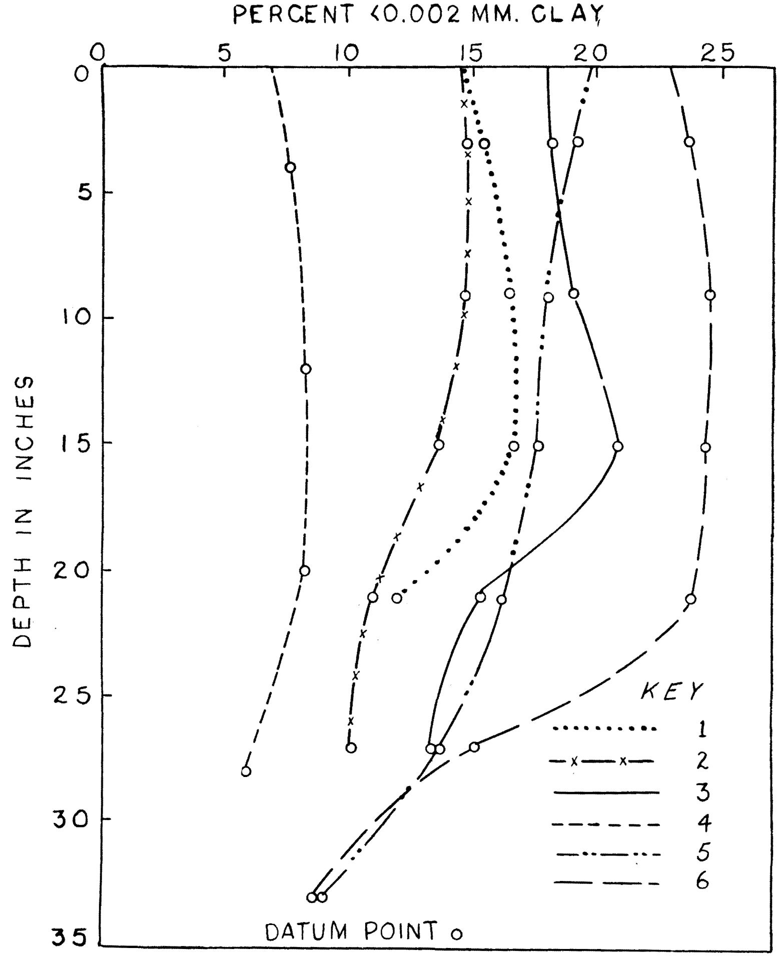

Figure 4. Percent clay with increasing depth in profiles.

Table 2

Porosity and Bulk Density

Profile No.	Depth	% Soil Solids	Total Porosity	Capillary Porosity	Bulk Densities
P389=1	0-6″	44.2	55.8	31.0	1.20
	6-12	42.3	57.7	27.6	1.27
	12-18	48.0	52.0	29.3	1.28
	18-24	49.4	50.6	25.8	1.34
	24-32				
P387=3	0-6	52.7	47.3	36.1	1.40
	6-12	48.8	51.2	36.1	1.31
	12-18	50.7	49.3	34.4	1.36
	18-24	53.3	46.7	32.7	1.43
	24-30	57.9	42.1	25.8	1.55
	30-36				
P388=4	0-8	48.8	51.2	24.1	1.37
	8-16	53.3	46.7	22.4	1.46
	16-24	51.4	48.6	20.6	1.43
	24-32	55.3	44.7	19.0	1.47
	32-40	58.5	41.5	17.2	1.57
P394=5	0-6	48.1	51.9	32.7	1.20
	6-12	44.9	55.1	32.7	1.37
	12-18	49.4	50.6	27.6	1.38
	18-24	48.8	51.2	31.0	1.50
	24-30	54.6	45.4	29.3	1.53
	30-36				
P395=6	0-6	44.2	55.8	41.3	1.22
	6-12	46.2	53.8	41.3	1.17
	12-18	42.9	57.1	38.9	1.20
	18-24	47.5	52.5	43.0	1.32
	24-30				
	30-36				

(No determinations on profile 2)

all profiles. The percent of sand increases as the underlying sands and gravel are approached.

Bulk Densities, Porosity, and Available Moisture Storage: The bulk density (apparent specific gravity) increased with depth in all profiles analyzed (Table 2). Decrease in organic matter and increase in sand with increasing depth in the profiles are probably causal factors. Bulk densities of profiles 3, 4 and 5 range from 1.2 at the surface to 1.55 as the underlying gravel is approached. As a whole these soils have higher bulk densities than the loess-derived soils of southwestern and southeastern Iowa (Ulrich, 1949; Hunter, 1950). Profile 6, which has bulk densities comparing closely with some of the loess-derived soils, is the lowest throughout the profile. Profile 1 ranges from 1.2 to 1.34 in the subsoil; no determinations were made on profile 2.

All of the profiles show a trend toward an increase in percent soil solids and a decrease in percent capillary porosity (a measure of moisture holding capacity) with increasing depth below the surface (Table 2).

Water storage capacities are graphically shown in Figure 5. A rather high drouth hazard can be predicted for these soils by com-

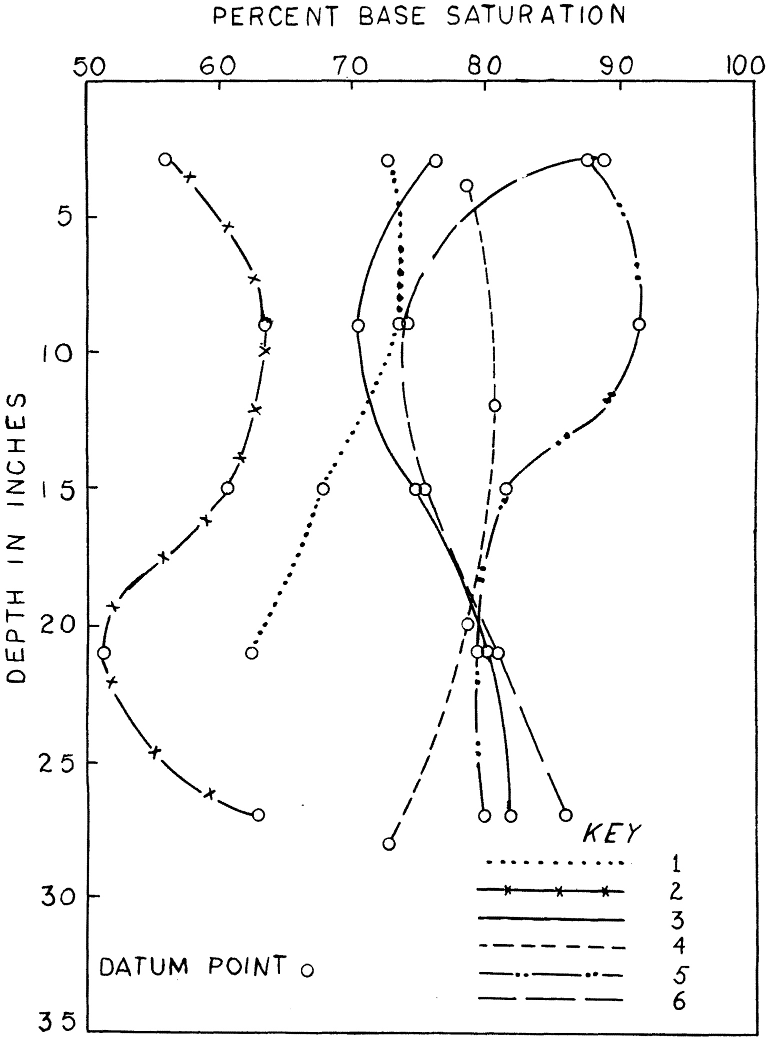

Figure 5. Percent base saturation with increasing depth in the profiles.

parison of their water storage capacity with the capacity of the Tama series (shown in Fig. 5), a highly productive loess-derived soil of east-central Iowa.

Nitrogen: The nitrogen content is apparently closely related to the percent clay in the profiles (Table 3, Fig. 4). Profile 6, which

Table 3

Exchangeable cations, pH, and nitrogen*

			Milliequivalents/ 100 grams						
Profile No.	Depth	pH	Ca	Mg	K	H	Cation Exchange Capacity	% Base Saturation	% N
P389=1	0-6"	5.6	8.13	1.54	0.18	3.72	13.57	72.6	0.140
	6-12	5.6	7.16	2.30	0.17	3.46	13.09	73.5	0.116
	12-8	5.5	5.93	1.50	0.17	3.62	11.22	67.7	0.094
	18-24	5.4	3.77	1.36	0.12	3.21	8.46	62.1	0.046
	24-30	5.1							
P390=2	0.6	5.3	4.88	1.35	0.24	5.00	11.47	55.8	0.164
	6-12	5.4	4.82	1.04	0.10	3.46	9.42	63.2	0.091
	12-18	5.3	3.88	1.22	0.13	3.44	8.67	60.3	0.070
	18-24	5.0	2.68	0.78	0.08	3.39	6.93	51.1	0.053
	24-30	5.0	3.26	1.18	0.11	2.62	7.17	62.7	0.021
	30-36	5.5							
P387=3	0-6	5.7	11.08	2.34	0.23	4.26	17.90	76.2	0.183
	6-12	5.4	9.44	2.02	0.17	4.91	16.54	70.3	0.142
	12-18	5.4	8.48	2.02	0.20	3.63	14.33	74.7	0.100
	18-24	5.4	7.40	2.21	0.19	2.45	12.25	80.0	0.074
	24-30	5.3	6.11	2.00	0.20	1.84	10.15	81.9	0.038
P388=4	0-8	5.8	4.62	1.77	0.16	1.81	8.36	78.4	0.089
	8-16	6.0	5.47	1.59	0.12	1.73	8.91	80.6	0.077
	16-24	6.0	4.74	0.81	0.12	1.52	7.19	78.8	0.059
	24-32	5.9	3.24	0.81	0.05	1.52	5.62	72.9	0.047
	32-40	5.7							
P394=5	0-6	6.2	12.74	3.61	0.14	2.37	18.86	87.4	0.154
	6-12	6.2	11.89	2.81	0.14	1.38	15.62	91.2	0.135
	12-18	5.8	8.76	2.81	0.12	2.66	14.35	81.5	0.104
	18-24	5.7	7.18	2.41	0.07	2.55	12.21	79.1	0.067
	24-30	5.6	5.49	2.60	0.08	2.06	10.23	79.9	0.056
	30-36	5.8							
	36-42	5.7							
P395=6	0-6	6.3	17.29	5.14	0.08	2.84	25.35	88.8	0.228
	6-12	5.1	12.20	3.91	0.07	5.80	21.98	73.6	0.184
	12-18	5.1	10.59	4.02	0.09	4.86	19.56	75.2	0.122
	18-24	5.2	9.56	4.54	0.09	3.41	17.60	80.6	0.073
	24-30	5.4	6.62	3.55	0.07	1.67	11.91	85.9	0.038
	30-36	5.5							

*Corrected for gravel.

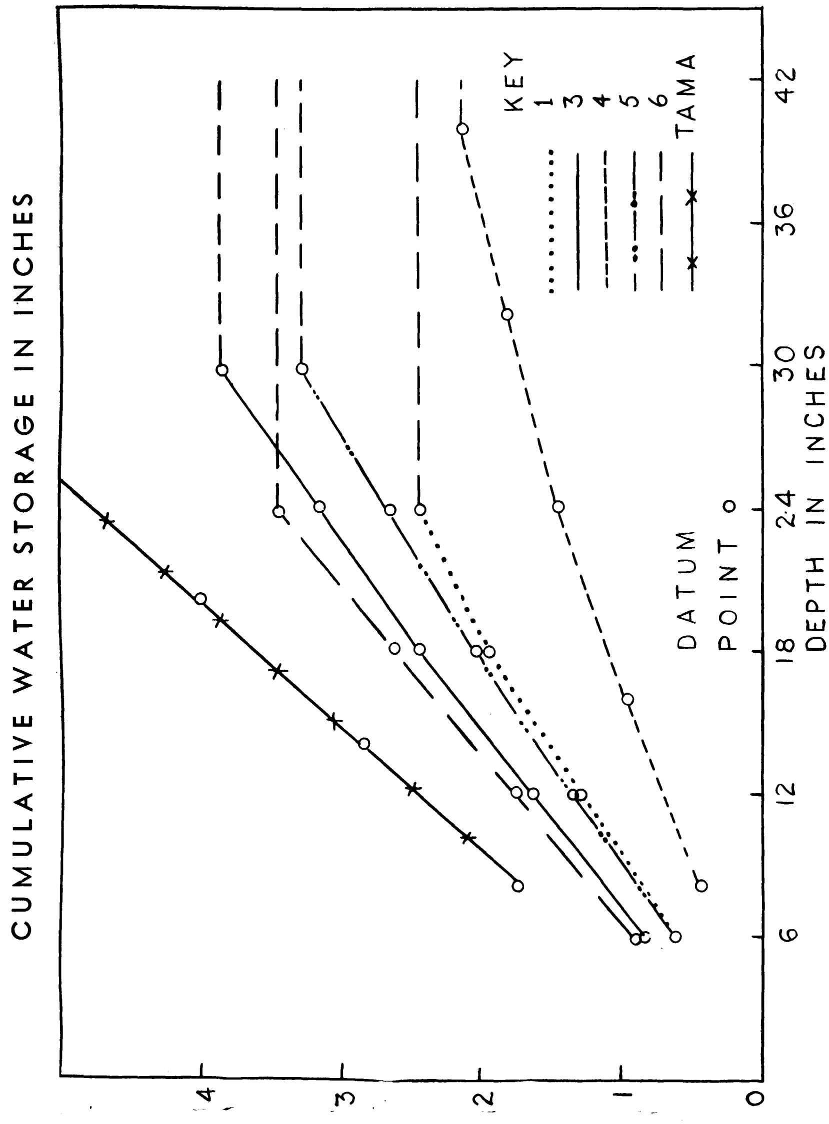

Figure 6. Water storage of profiles sampled as compared to Tama soil.

is the highest in clay content, is also highest in nitrogen. Profile 4 is the lowest in clay content and also the lowest in nitrogen.

Exchangeable Bases and Exchange Capacity: Exchangeable cations and cation exchange capacities of the profiles sampled are presented in Table 3. (Data for "exchangeable cations" represents the amounts of cations held on the exchange positions of the soil colloids, expressed in milliequivalents per 100 grams of dry soil).

The cation exchange capacity is apparently closely related to the amount of clay and organic matter in the profiles. The total amount of exchangeable calcium decreases with increasing depth in the profiles, but exchangeable magnesium and potassium tend to be uniform throughout. The exchangeable potassium content is considerably lower than in some of the loess-derived soils of southern Iowa (Ulrich, 1949; Hunter, 1950) but is about equal to that of some of the soils derived from Iowan till (White, 1950).

The percent base saturation (Fig. 6), the ratio of total exchange positions or exchange capacity to the amount of bases actually present on the exchange positions, corresponds fairly well with the pH data (Table 3). The percent base saturation may be taken as an approximation to the degree of weathering the soil has undergone. The two profiles from the Iowan terraces, profiles 1 and 2, have the lowest percent base saturation and have lower pH values than the profiles from the Late Wisconsin terraces. If it can be assumed that the original parent material was entirely base saturated, the base saturation data would indicate that the soils from the Iowan terraces are older and somewhat more strongly leached.

Potassium Release Studies: Release of potassium, an important plant nutrient, from nonexchangeable forms to forms available for plant uptake was studied by two methods—extraction with nitric acid and with Dowex 50 cation exchange resin. A high correlation was found between these two methods. Details are described elsewhere by the senior author (Coultas, 1951). Potassium release by these soils compares favorably with that of soils derived from Late Wisconsin and Iowan till, but none of the samples gave as great a release as loess-derived soils of southwestern Iowa (Pratt, 1950).

Approximately one-fourth of the total potassium release from nonexchangeable forms was from the sand fraction (particles greater than 0.05 mm. in diameter). This important source of potassium from the sand fraction and the lower rate of potassium supply from these soils as compared to loess-derived soils of southwestern Iowa points up the desirability of additional lithological and mineralogical studies of the Wisconsin glacial drift in northcentral and northeastern Iowa.

SUMMARY AND CONCLUSIONS

Wisconsin terrace gravels and sand are found along nearly every stream in the regions of Wisconsin glaciation in Iowa. About 600 square miles of well-drained soils developed on the terraces have been recognized in Iowa. These soils have commonly been classified with one soil series--the O'Neill series.

Geological investigations (Kay and Miller, 1941) have demonstrated a dominant condition of "silty overburden" of varying thickness over the terrace gravel and sand of both Iowan and late Wisconsin age.

Variations in the texture (particle size distribution) and thickness of this "overburden", which are properties observable in the field, are reflected in significant co-variations of important physical and chemical properties of the soils. These relationships were determined by describing and sampling six soil profile sites followed by laboratory determinations of textures, bulk densities, porosities, nitrogen content, exchangeable bases, cation exchange capacity, and potassium release of these soils. Two of these soil profiles were from outwash terraces of Iowan age, the remaining four were obtained from terraces of Late Wisconsin age.

The ranges in properties, as observed in the field and measured in the laboratory, indicate that at least three soils series should be recognized where one, the O'Neill series, has been recognized previously. This will enable more precise use and management recommendations and evaluations of ability to produce to be made.

Use of laboratory methods, such as percent base saturation, to establish weathering trends and to determine degree of leaching are described. These studies indicate the soils developed on the Iowan terraces are apparently more leached.

Determination of potassium release into exchangeable forms by nitric acid and Dowex 50 exchange resin indicate that about one-fourth of the release comes from the sand fraction.

Problems such as age discrimination, variations in lithology and size-sorting of the terrace materials, are common to soil science and geology. Aid of Pleistocene geologists is solicited in investigation of these problems in order that satisfactory classification and mapping of the soils developed on the terraces may be accomplished.

Reference Cited

1. Beyer, S. W., 1914. The Road and Concrete Materials of Iowa. Ia. Geol. Surv. 24:33-685.
2. Coultas, C. L., 1951. Properties of Some Profiles of the O'Neill Series. Unpublished M.S. thesis, Iowa State College, Ames, Iowa.
3. Hunter, R., 1950. Physical Properties of Some Loess-Derived Prairie Soils of Southeastern Iowa. Unpublished M.S. thesis, Iowa State College, Ames, Iowa.
4. Iowa Agricultural Experiment Station and U. S. Dept. of Agriculture, Div. of Soil Survey: Soil Survey Reports of Iowa Counties.
5. Kay, G. F. and Miller P. T., 1941. The Pleistocene Gravels of Iowa. Ia. Geol. Surv. 37:1-232.
6. Pratt, P. F., 1950. Release of Potassium from Nonexchangeable Forms in Iowa Soils. Unpublished Ph.D. thesis, Iowa State College, Ames, Iowa.
7. Ulrich, R., 1949. Some Physical and Chemical Properties of Planosol and Wiesenboden soil series as Related to Loess Thickness and Distribution. Unpublished Ph.D. thesis, Iowa State College, Ames, Iowa.
8. White, E. M., 1950. Profile Properties of Some Variants of the Carrington Series in Iowa. Unpublished M.S. thesis, Iowa State College, Ames, Iowa.
9. Wood, L. W., 1935. The Road and Concrete Materials of Southern Iowa. Ia. Geol. Surv. 36:14-310.

Appendix

Locations of Soil Profiles Sampled in this Study

Profile 1: Delaware County, Iowa; NE corner of the SE¼, SE¼, Section 23; R.6W., T.89N.; Prairie Creek terrace.

Profile 2: Delaware County, Iowa; NW corner of the SW¼, SW¼, Section 19; R.5W., T.89N.; Prairie Creek terrace (one mile east of Profile 1).

Profile 3: Butler County, Iowa; NW corner of the NW¼, SW¼, Section 1; R.16W., T.92N.; Shellrock River terrace.

Profile 4: Butler County, Iowa; center of Section 2; R.16W., T.92N.; Shellrock River terrace.

Profile 5: Polk County, Iowa; NW¼ of NW¼, SW¼; R.25W., T.81N.; Mosquito Creek terrace.

Profile 6: Worth County, Iowa; SW¼ of the NE¼, SW¼, Section 8; R.20W., T.99N.; Shellrock River terrace.