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Free Iron Distribution in Some Poorly Drained Prairie Soils in Iowa[1]

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In classification and mapping of soils an interpretation of the natural drainage characteristics of the soil types is usually made. Some standard natural drainage classes used are poorly drained, imperfectly drained, moderately well- drained, and well-drained (1). Interpretation of the natural drainage of the soils is important from the agronomic standpoint, and also is basic to the soil classification scheme in present use.

The natural drainage of a soil is interpreted mainly by inferences from the color and mottling of hydrated iron oxides in the subsoil. Few studies have been made of the nature and quantity of these iron oxides in soils. Extractable iron or "free iron" has been determined in a few well-drained Brunizem and Gray Brown Podzolic soils, and in several poorly drained Forested Planosols (2) (3) (4) (5).

The purpose of this paper is to report data on free iron in several poorly drained prairie (Wiesenboden) soils and to compare these data with available data of other great soil groups in Iowa.

Method of Free Iron Determination

The profiles were analyzed for free iron by the Jefferies method as outlined by Swenson (6) and modified by White (2). Determinations were made on one gram samples of air-dried soils which were ground to pass through a 40-mesh screen. The samples were treated with hydrogen peroxide to remove the organic matter.

In this method the iron is reduced and brought into solution by heating in an oxalic acid-potassium oxalate buffered solution with magnesium ribbon. The iron content of the filtrate is determined colorimetrically with an Evelyn colorimeter using the orthophenanthroline method. The results are reported as percent free iron of the whole soil.

The free iron determination is an empirical method and the results depend somewhat on the procedure used. Some studies (2) (7) have indicated that varying the time of extraction and temperature of

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treatment may affect the results. There is some indication that not all forms of concretionary iron are readily dissolved. Haldane (7) has stated that lattice iron of certain iron rich secondary minerals may be partially dissolved. Swenson (6) has presented evidence that this source of error probably is not appreciable in loess derived soils of Iowa.

The free iron percentages of all the soils compared in this paper were determined by the method used with the Wiesenboden soils in this study.

Free Iron in Some Wiesenboden Soils

The distribution of free iron with depth is reported in table 1 for ten Wiesenboden soils of Iowa. Eight of these profiles—three of the Taintor series, four of the Haig series, and one of the Garwin series—are poorly drained prairie-formed soils developed from loess on upland flats of southeast Iowa. These profiles were selected as representative of the range of Wiesenboden soils in southeast Iowa. Schafer (8) has reported clay and other data for these soils. Free iron also is given for two profiles of the Webster series which are poorly drained prairie soils developed from loam glacial drift of Mankato age. The data for P-466 are those reported by McCracken (9).

The average clay and free iron content of the A_1 and B_2 horizons of the ten Wiesenboden soils is presented in table 2. Also given are ratios of clay to free iron calculated by dividing the average percent of 0.002 mm. clay[1] by the average percent free iron. Included in table 2 for comparison is a similar summary of available data on soils of several other great soil groups in Iowa on which free iron was determined by the method used in this study.

In figure 1 the clay and free iron percentages with depth are plotted for P-165, a profile of the Taintor series, one of the Wiesenboden soils studied. Also shown are plots of equivalent data for representative profiles of the Brunizem, Gray Brown Podzolic, and Forested Planosol great soil groups in Iowa. Data for the Brunizem profile (Galva P-247) are by Foth (3); for the Gray Brown Podzolic (Weller P-3) by White (2); and for the Forested Planosol (Berwick P-423) by Cain (5).

Discussion

The data set out in figure 1 and recorded in table 1 show that the Wiesenboden soils have a lower content of free iron than the regional

[1]All clay data referred to in this paper are by the standard pipette procedure for less than 0.002 mm. clay which method has been described by White (2).

Table 1

Percent Free Iron and Ratio of Clay to Free Iron with Depth in Profiles of Ten Wiesenboden Soils of Iowa

Horizon	Depth	% Fe	Ratio Clay/Free Fe	Horizon	Depth	% Fe	Ratio Clay/Free Fe
P-415 Garwin				P-412 Taintor Silty Clay Loam			
A_{1p}	0-7	0.64	48	A_{1p}	0-7	0.45	81
A_1	7-11	0.71	49	A_1	7-11	0.54	74
A_1	11-15	0.74	48	A_3	11-15	0.62	65
A_3	15-18	0.79	47	B_1	15-18	0.74	56
B_1	18-21	0.87	44	B_{2g}	18-21	0.89	49
B_2	21-24	0.82	48	B_{2g}	21-24	1.14	36
B_{2g}	24-28	0.87	47	B_2-B_{3g}	24-28	1.14	35
B_{3g}	28-33	0.68	57	B_{3g}	28-35	1.66	22
B_{3g}	33-40	0.88	40	C_1	35-42	0.32	101
C	40-50	0.95	34	C_2	54-66	0.86	31
C	50-64	1.11	27				
P-410 Taintor Silty Clay Loam				P-165 Taintor Silty Clay Loam			
A_{1p}	0-6	0.49	70	A_1	0-5	0.46	73
A_1	6-9	0.45	85	A_1	5-9	0.48	74
A_3	9-14	0.49	84	A_3	9-14	0.50	74
B_2	14-17	0.59	73	B_1	14-19	0.60	67
B_{2g}	17-20	0.64	67	B_2	19-24	0.65	65
B_{2g}	20-23	0.80	56	B_{2g}	24-28	0.65	63
B_{2g}	23-27	1.01	44	B_{3g}	28-33	0.71	53
B_{3g}	27-33	1.11	36	B_{3g}	33-38	0.52	64
B_{3g}	33-40	1.15	32	B_{3g}	38-45	0.86	37
C	40-48	0.45	75	C	45-52	0.30	92
C_2	60-70	0.71	35	C	52-60	0.38	46
C_2	75-85	0.41	69				
P-414 Haig Silty Clay Loam				P-164 Haig Silt Loam			
A_{1p}	0-7	0.56	50	A_1	0-6	0.53	50
A_1	7-11	0.60	54	A_1	6-10	0.56	52
A_1	11-14	0.65	55	A_1	10-14	0.63	54
A_3	14-18	0.70	58	A_3	14-18	0.71	53
B_2	18-21	0.76	60	B_2	18-24	0.84	57
B_{2g}	21-24	0.90	52	B_{2g}	24-30	0.81	56
B_{2g}	24-28	0.80	55	B_2-B_{3g}	30-36	1.02	39
B_{3g}	28-34	0.93	44	B_{3g}	36-43	0.85	43
B_{3g}	34-40	0.98	37	C_g	43-50	1.18	28
C	40-52	0.82	38	C	50-60	0.30	97
C	52-68	1.18	24				

Table 1—Continued

Horizon	Depth	% Fe	Ratio Clay/Free Fe	Horizon	Depth	% Fe	Ratio Clay/Free Fe
P-413 Haig Silty Clay Loam				P-411 Haig Silty Clay Loam			
A_{1p}	0-7	0.54	57	A_1	0-6	0.51	58
A_1	7-10	0.58	55	A_1	6-10	0.53	61
A_1	10-14	0.58	61	A_3	10-14	0.62	61
A_3	14-17	0.60	64	B_2	14-17	0.71	59
B_2	17-20	0.64	66	B_{2g}	17-20	0.90	51
B_2	20-23	0.67	68	B_{2g}	20-23	1.05	44
B_{2g}	23-27	0.85	56	B_{2g}	23-27	0.92	47
B_{2g}	27-33	0.84	53	B_{3g}	27-34	1.04	38
B_{3g}	33-38	0.91	42	C_1	34-40	0.91	39
B_{3g}	38-44	0.82	45	C	40-48	0.88	35
C_1	44-52	0.92	29	C	60-70	0.61	44
C	65-75	0.80	43	C	80-90	0.23	100
46519-28 Webster Silty Clay Loam				P-466 Webster Silty Clay Loam[1]			
A_1	0-8	0.39	88	A_h	0-12	0.23	172
A_1	8-12	0.36	94	B_{g1}	15-20	0.28	144
A_3	13-17	0.37	94	B_{g2}	20-24	0.23	172
B_{2g}	17-21	0.34	100	C_{g1}	29-36	0.22	134
B_{3g}	21-26	0.40	79	C_{g2}	36-60	0.31	79
C_1	26-31	0.35	80				
C	31-37	0.33	73				
C	37-43	0.38	63				
C	43-50	0.39	63				
C	50-60	0.53	46				

[1]Data from McCracken (9).

associated naturally better drained Brunizem and Gray Brown Podzolic soils. The surface horizons of the Wiesenboden soils are lowest in free iron which is interpreted here to reflect the naturally poor drainage conditions under which these soils formed. These conditions evidently favor the reduction of iron, increasing its mobility, and resulting in its movement out of the upper part of the solum.

The ratios of clay to free iron for the Wiesenboden soils (table 2) are consistently higher in the A_1 or A_p and B_2 horizons than in comparable horizons of the Brunizem and Gray Brown Podzolic soils, demonstrating the lower free iron content of the poorly drained Wiesenboden soils. However, the ratios of the Wiesenboden group vary considerably between soils and average somewhat lower in the B_2 than the A_1 or A_p horizons. Furthermore, the maximum free iron does not, in any of these profiles, correspond to the horizon of maximum clay accumulation (B_2). It seems that the free iron is not associated with clay distribution in the poorly drained Wiesenboden soils in the same manner that clay and free iron are associated in the Brunizem and Gray Brown Podzolic soils.

The reason for the variability in percent of free iron below the B_2 horizons of the Wiesenboden soils is not apparent. Perhaps it is related in some way to the shallowness and variability of the ground water table. The Taintor profiles sampled in areas associated with

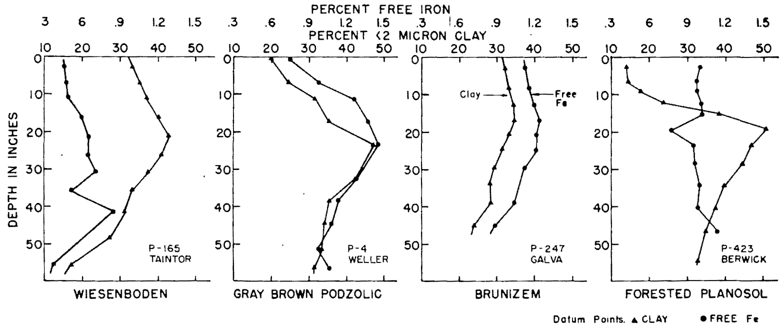

Figure 1. Distribution of Free Iron and Clay with Depth in Representative Profiles of the Wiesenboden, Gray Brown Podzolic, Brunizem, and Forested Planosol Great Soil Groups in Iowa.

the Haig series were interpreted by Schafer (8) to be somewhat more poorly drained and to have a higher ground water level. Possibly this is related to the greater variability, as shown in table 1, of free iron content in the lower horizons of the Taintor profiles compared with the Haig profiles.

The two Webster profiles are especially low in free iron content. Whether this is due to differences in parent material or to some unidentified difference in genetic factors is not known. It can be pointed out that the Webster soils are formed from Late Wisconsin Glacial Till and are younger geologically and less well-developed pedologically than the Taintor and Haig series.

Cain (5) has previously reported and discussed free iron data for four poorly drained Forested Planosols. Certain of these data are summarized in table 2 and plotted in figure 1. It can be seen that in these poorly drained soils, as in the Wiesenbodens, there is no positive correlation between the distribution of free iron and clay with depth in the profile.

The higher level of free iron in the upper horizons (A_1, A_2) of the Forested Planosols, as compared to the Wiesenboden soils, is probably due to greater weathering and greater retention of iron, mainly in concretionary forms. A perched water table may be expected to occur frequently in these soils and may influence free iron retention in the upper horizons.

The well drained Brunizem and Gray Brown Podzolic soils, in contrast to the poorly drained soils, show a close association between clay and free iron distribution with depth in the profile. In table 2 it is seen that the average clay to free iron ratios of the A_1 and B_2 horizons are nearly the same in both well drained groups of soils. This illustrates the marked tendency for clay and free iron to co-accumulate in the B_2 horizon of the naturally better drained soils.

Table 2

Clay and Free Iron Relationships in the Major Horizons of Several Brunizem, Wiesenboden, Gray-Brown Podzolic, and Forested Planosol Soils Formed from Medium Textured Parent Materials

		Horizons								
		A_1 or A_p			A_2			B_2		
Great Soil Group	No. of Profiles	Clay	Free Fe	Ratio Clay/Free Fe	Clay	Free Fe	Ratio Clay/Free Fe	Clay	Free Fe	Ratio Clay/Free Fe
		(%)	(%)		(%)	(%)		(%)	(%)	
Wiesenboden	10	33	.49	68		[a]		43	.73	59
Brunizem	12	30	1.1	27		[a]		34	1.20	28
Gray-Brown Podzolic	6 4	17.6	.68	25	17	.73	24	35	1.36	27
Forested Planosols		17	.96	18	20	1.13	17	51	.97	53

[a] A_2 horizon absent.

Table 3

Percent Free Iron and Percent < .002 mm. Clay in the A_1 Horizons of Several Different Textured Brunizem Soils

Profile	Depth	Percent Clay	Percent Free Fe	Ratio Clay/Free Fe
Thurman loamy sand P-445[1]	0-6	3.66	.19	18
Dickinson sandy loam P-446[1]	0-10	12.5	.35	36
Clarion loam P-49[2]	0-12	23.8	.98	24
Galva silty clay loam P-247[3]	0-11	31.0	1.14	27

[1]Data from Folks (1954).
[2]Data from Green (1952).
[3]Data from Foth (1952).

The same relationship is shown graphically in figure 1 in the Weller and Galva profiles. The excellent and consistent correlation of clay and free iron concentration in well drained soils has been pointed out in several previous studies (2) (3) (9).

In calculating the ratios for the well drained soils a strong tendency was noted for the soils higher in clay to be higher also in free iron. Data on the free iron content of the A_1 horizons of coarse textured Brunizem soils were compared with data for finer textured Brunizem soils to examine the relation of texture to free iron content (table 3). These data indicate that there is a fairly good correlation between soil texture and content of free iron in well drained Brunizem soils of Iowa. Other data (3) (4) (10) indicate that the same relationship exists in the Gray Brown Podzolic soils of Iowa.

It is interesting to note the similarity in the average ratios of clay to free iron in the Brunizem and Gray Brown Podzolic great soil groups. This seems to indicate general similarity in the soil forming processes with respect to clay and free iron accumulation in these two groups of soils.

Summary and Conclusions

Data are presented on the free iron distribution in ten Wiesenboden profiles, and comparison is made with available data of the Forested Planosol, Brunizem, and Gray Brown Podzolic great soil groups in Iowa.

The Wiesenboden soils studied are lower in free iron than the well drained soils. Free iron in the Wiesenboden soils is uniformly low in the A_1 horizons. This is believed to be due to the greater mobility and removal of iron from the profile under poor drainage conditions and grassland environment.

The poorly drained soils do not show an association of clay and free iron in the profile such as is evident in the well drained Brunizem and Gray Brown Podzolic soils. Thus the factors which cause mutual occurrence of clay and free iron maximum concentrations in well drained soils are not effective in poorly drained soils.

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