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post 1937 ~1938

Weathering of loess in Illinois

by

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Introduction

The first work on soil formation in Illinois by the Illinois Soil Survey of the College of Agriculture of the University of Illinois followed, to a large degree, the Russian School[1] of Soil development. Accordingly weathered profiles were divided into three horizons as follows:

Horizon A : Zone of eluviation: material has been removed and carried to a lower horizon.

" B : Zone of accumulation: material has been added from Horizon A.

" C : Zone of unweathered or slightly weathered parent material.

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[1] Glinka, D., Die Typen der Bodenbildung, ihre Klassifikation und geographische Verbreitung. Gebruder Borntraeger, Berlin, 1914.

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Detailed field studies by Smith and Norton,_/ of the Illinois Soil Survey, and Leighton and MacClintock,_/ of the Illinois Geological Survey soon led to the recognition that the Russian system of horizon nomenclature was inadequate because it failed to fully recognize or provide for the possibility of the occurrence of a zone or zones of alteration beneath the zone of accumulation. Norton and Smith_/ on the basis of studies of weathered surface loess divided the former C horizon into C, D, and E horizons as follows: C, a zone of alteration without appreciable accumulation; D, zone of slight alteration containing some primary carbonates; E, unaltered parent material. Leighton and Mac Clintock_/ on the basis of studies of weathered buried drift sheets divided the weathering profile for this material as follows:

_/ Norton, E. A., and Smith, R. S., Horizon designations: Bull. IX, Am. Soil Surv. Assoc. pp. 83-86, (1928).

Smith, R. S., and Norton, E. A., The structural anatomy of the soil profile: Bull X, Am. Soil Surv. Assoc. pp. 35-37 (1929).

_/ Leighton, M. M., and MacClintock, P., Weathered zones of the drift sheets of Illinois: J. Geol. 38, pp. 28-53 (1930).

_/ Norton, E. A., and Smith, R. S., Idem. 1928.

_/ Leighton, M. M., and MacClintock, P., Idem. 1930.

Horizon 1 : surficial soil.

" 2 : zone in which material is oxidized, leached, and all but most resistant constituents chemically decomposed.

" 3 : zone in which material is oxidized and leached.

" 4 : zone in which material is oxidized.

" 5 : zone of unweathered material.

It was also shown that the weathering profiles developed on surface deposits were relatively less mature, i.e., alteration had progressed less far, than the profiles developed on buried deposits.

The effect of topography and drainage on horizon development was recognized by the above workers. Norton and Smith_/ described the influence of these factors on surface loess profiles, and Leighton and MacClintock_/ described their influence on buried drift profiles. The concept of the latter workers is given in Fig. 1.

_/ Norton, E. A., and Smith, R. S., The influence of topography on soil profile character: J. Am. Soc. of Agron. 22, pp. 251-262 (1930).

_/ Leighton, M. M., and MacClintock, P., Idem. 1930.

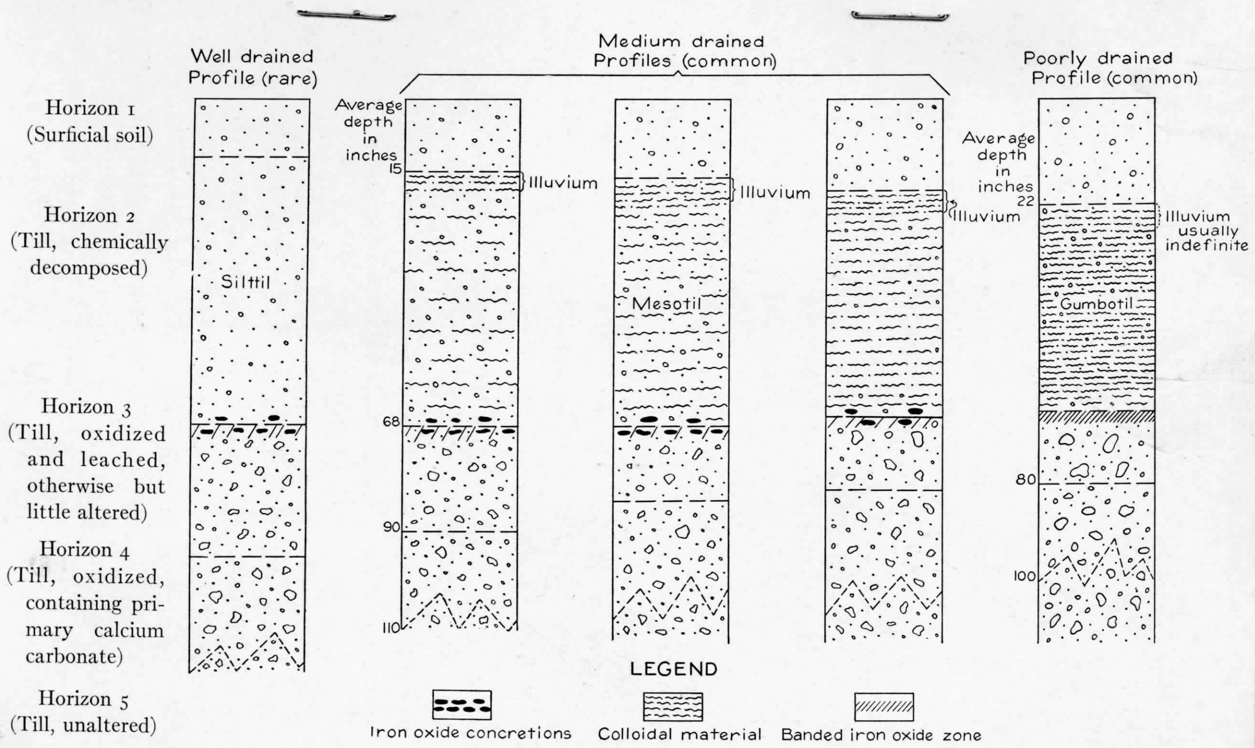

FIG. 1.—Diagrammatic summary of the gradational series of weathered profiles on the Illinoian drift in southern Illinois, from the well-drained to the poorly drained types (thicknesses given are averages from computations made by courtesy of R. S. Smith and E. A. Norton, Illinois State Soil Survey).

In the course of the intensive study of Illinois soils which the Illinois Soil Survey has made, particular attention has been paid to the loessial soil because most Illinois soils are of this type. Attention has been given to the distribution and characteristics of the loess[1] and the weathering changes and resulting soils developed on it.

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[1] Smith, R. S., Norton, E. A., Winters, E., and Wascher, H., Parent material, subsoil permeability and surface character of Illinois soils: Univ. of Illinois, College of Agriculture, 1935.

A considerable number of chemical studies have also been recently made which have thrown light on the development of these loess soils._/ In the latter part of the chemical study of loessial soils, the Illinois State Geological Survey has cooperated in supplying petrographic analyses and interpretations from the mineralogical and geological point of view. On the basis of this work the profiles developed on loess by present weathering have been divided into the following horizons;

Horizon I : The surficial soil. The horizon of eluviation, containing fewer colloidal silicates than were formed in place.

Horizon II : The horizon of illuviation, containing more colloidal silicates than were formed in place.

Horizon III : Colloidal silicates present mainly formed in place.

Horizon IV : Similar to Horizon III except for the presence of primary carbonates.

Horizon V : Relatively unchanged parent material.

This division of the profile into horizons recognizes the large part played by the formation and movement of colloidal silicates in horizon development in these soils which led one of us (Bray) to name this type of development, the silicatic type of soil

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_/ Bray, R. H., Base-exchange capacity studies on certain soil types in Illinois: Am. Soil Survey Assn. Bull. XI, 161-168 (1930).

Bray, R. H., A chemical study of soil development in the Peorian loess region of Illinois: Amer. Soil Survey Assn. Bull. XV, pp. 58-65 (1934).

Bray, R. H., The origin of horizons in claypan soils: Amer. Soil Survey Assn. Bull. XVI, pp. 70-75 (1935).

development._/ These divisions are applicable to most of the profiles in Illinois. They vary from the divisions proposed by Norton and Smith and by Leighton and MacClintock in that the movement of the colloidal silicates, is used as the basis for separating the three main weathered horizons, i.e., Horizons I, II, and III, although in general the major concepts of the Russian system and the above mentioned modifications of the Russian system are retained. Subdivisions of the main horizons are given letters, a, b, c, etc.

The present paper presents the results secured from the cooperative study of the weathering of loess in Illinois [made by the Soil Survey Analysis Division of the Agronomy Department of the University of Illinois and the Illinois State Geological Survey.) It is proposed here to discuss in detail the mineralogical, textural, and chemical changes taking place under present day conditions of weathering. These data may be taken as illustrative of the general results of weathering in a climate of the type prevailing in Illinois and on unconsolidated rocks of about the composition of loess. If the Russian philosophy of soil formation is accepted which considers climate as the dominant determative factor, the data are illustrative of the weathering effects on any kind of parent rock in a similar climate. In Illinois a humid temperate climate characterized by warm summers and cold winters prevails. The mean summer temperature is about 75°, the mean winter temperature is about 32°, the growing season is 170 to 192 days and the rainfall is 30 to 40 inches. A fairly uniform distribution of the rainfall occurs.

_/ Bray, R. H., Idem. 1935.

The soil resulting from the weathering processes affecting the loess is of the podsol type although not a true podsol since it does not have the accumulation of humus matter and free oxides in $H_o$rizon II that is characteristic of typical members of this large group of soils.

Distribution and age of loess in Illinois

(write-up by M. M. L.)

(including map in which location of sections of loess studied are given)

Procedure

Sections of Peorian loess at three localities increasing distances southeast of Mason County, Illinois, were studied in detail. They represent material occurring under conditions of poor subsurface drainage which, for the following reasons has been subjected to increasing amounts of weathering. (1) The loess in this area had its source in the Illinois River valley, and, consequently, it is thickest and its deposition continued longest directly adjacent to the valley. Weathering processes, therefore, were of prime importance at some distance southeast of Mason County while deposition was still dominant in Mason County. (2) There is a slight increase in the length of the frost-free season southeastward from Mason County, which increases slightly the relative rate of weathering in this direction. (3) The loess in this area is immediately underlain by gumbotil. The effect of decreasing thicknesses of loess southeastward with such underlying material in poorly drained areas is to make them even less well drained. Poorer drainage results in an increased rate of weathering after the removal of carbonates.

Samples were collected from each section of loess from several horizons (see profile descriptions) from the surface downward. Samples from each horizon were thin sectioned, and fractionated by the supercentrifuge technique of Bray, Grim and Kerr.[1] In this

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[1] Bray, R. H., Grim, R. E., and Kerr, P. F., Application of clay mineral technique to Illinois clay and shale: Bull. Geol. Soc. of Am. 46, pp. 1909-1926 (1935).

method the original material is fractionated into:

R - Residue +1 micron

C - Coarse Colloid Fraction 1-.1 micron

F - Fine Colloid Fraction .1-.06 micron

S - Very Fine Colloid Fraction -.06 micron

Mineralogical identifications based on the optical, X-ray[1] and chemical analytical data were obtained for each colloid fraction of most horizon samples. The constituents of the residue were identified by means of their optical properties. Since all sections of loess studied in this sequence occurred under poorly drained conditions, possessed original loess of about the same texture and mineral composition, and had about the same plant growth covering (prairie), these particular factors, which may influence weathering effects, were held constant.

Additional series of samples from the various horizons, from the surface down to unweathered loess, were collected and studied from other sections of loess occurring under well drained conditions, and possessing a different plant cover.

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[1] X-ray analyses were made by Prof. P. F. Kerr, of Columbia University, New York City.

Weathering of loess under conditions of poor subsurface drainage

The locations of the sections of loess studied which yielded the data on which the following discussion is based are given in figure 2. The section in Menard County which has undergone the least weathering represents what is here designated as Stage 1. The section in Fayette County, which has undergone the most weathering, represents what is here called Stage 5. The section in Christian County represents an intermediate weathering stage designated as Stage 3. Detailed descriptions of the sections studied from the surface downward are given in Tables I, II, and III. The analytical data and mineral identifications for all fractions of the horizons studied are given in Tables IV, V, and VI.

The vertical distribution and abundance of the mineral constituents of Stage 1 and Stage 5 are shown diagrammatically in Figures 3 and 5. These diagrams illustrate the fact, discussed in detail later in the paper, that there has been vertical movement and concentration of some constituents in the weathering of the loess. In order to emphasize this point, the data for Stage 1 have been recalculated on the basis of no vertical movement. The results of these calculations, portrayed in Figure 4, have been obtained by the following procedure. The aluminum content (corrected for carbonates) of the lowermost horizon which is unweathered loess and where neither gain nor loss of material has occurred, was taken as the original aluminum content. The increase in aluminum content in horizon II above this value was converted to the equivalent percentage of superfine colloid and a corresponding subtraction made.

TABLE 1

Profile description of Stage 1

Type: Number 44, Hartsburg silt loam (formerly Monmouth)

Location: T 18 N, R 7 W, Section 6, NE 1/4 NE 40, NE 10. Menard County

Topography: Slight slope to NE. Calcareous at 33" - water table at 70". Vegetation originally prairie - now roadside sod

Sampled by: E. A. Norton and R. H. Bray 8-3-32

Number	Horizon	Depth	Description	Colloids Percent 1 micron*	Percent Org. Carbon*	Percent $CaCO_3$ Equiv.*
14034	Ia	0-8 "	Black laminated silt loam	22.3	2.53	None
14035	Ib	8-14"	Subangular particles - clayey siltloam	25.3	1.46	"
14036	Ic	14-18"	Transition to IIa. Subangular - coated drab brown	31.0	.86	"
14037	IIa	18-24"	Prisms 1-1 1/2". Coated drab brown. Inside color yellowish gray. Slightly compact clay loam	31.6	.67	"
14038	IIb	24-31"	Similar to IIa. Less compact. Red yellow splotches	26.3	.41	"
14039	IVa	33-40"	Calcareous (secondary and primary) friable silt, pale yellowish gray	17.0	.40	8.2
14040	IVb	40-52"	Similar to IVa. Splotched red yellow	10.7	.30	17.0
14041	IVc	52-64	Very friable. Similar to IVb. Small land snail shells	8.0	.25	24.0
14042	IVd	64-72"	Very friable. Similar to IVc. Large lime concretions up to 5" long.	7.0	.25	27.0

Calcareous loess to 190", showing little difference from IVc and IVd. Not studied below 190". IVd has slightly more red color indicating some Fe_2O_3 accumulation due to drainage conditions.

*Determinations by Eric Winters.

TABLE II

Profile description of Stage 3

Type: Number 127, Harrison silt loam

Location: T 13 N, R 2 W, Section 6, NE 1/4 NE 40, SE 10. Christian County

Topography: Very gentle slope to north. Vegetation originally prairie - now roadside sod

Sampled by: R. H. Bray and E. A. Norton 9-16-32

Number	Horizon	Depth	Description	Colloids Percent 1 micron*	Percent Org. carbon*
14065	Ia	0-7 "	Laminated, friable, grayish brown silt loam	15.4	1.89
14066	Ib	7-13"	Very small particle structure. Friable	17.6	1.66
14067	Ic	13-18"	Transition. Prisms begin. Particles coated brownish black, heavily gray specked	25.6	1.18
14068	IIa	18-25"	Prisms 1 1/2 to 4". Coated brownish black. Compact and medium plastic	38.4	.76
14069	IIb	25-31"	Coatings more drab than above. Inside color lighter	35.3	.49
14070	IIc	31-38"	Slightly compact and plastic. More yellowish color than above	29.4	.34
14071	IIIa	38-48"	Transition. Prisms absent. Very slightly compact. Numerous dark brown pellets.	22.8	.23
14072	IIIb	48-60"	Very friable. Gray splotched with yellow	16.1	.08
14073	IIIc	60-68"	Light gray splotched with yellow. Very friable	15.4	.08
14074	IIId	68-74"	Darker colored loess on weathered till.	14.5	.14

Loess 74" deep. Carbonates absent.

*Determined by Eric Winters.

TABLE III

Profile description of Stage 5

Type: Number 2, Cisne silt loam (U. S. Bureau = Corey)

Location: T 7 N, R 1 E, Section 4, NE 1/4 NE 40, NE 10. Fayette County.

Topography: Slope very gentle to NE. Vegetation originally prairie - now roadside sod.

Sampled by: R. S. Smith, E. A. Norton, and D. C. Maxwell.

Number	Horizon	Depth	Description	Colloids Percent 1 micron*	Percent Org. carbon*
14083	Ia	0-8 "	Brownish gray friable silt loam. Laminated	12.0	1.51
14084	Ib	8-14"	Light brownish gray. Friable	12.2	.77
14085	Ic	14-21"	Ashy gray layer. Numerous iron concretions at 20 1/2 to 21". No transition horizon	9.0	.32
14086	IIa	21-31"	Prismatic. Heavily gray coated. Very compact and plastic. Inside color yellowish gray with yellowish brown splotching	42.0	.53
14087	IIb	31-38"	Less coating. More splotching than IIa	37.1	.37
14088	IIc	38-46"	Less compact and plastic - more gray than IIb	28.8	.22
14089	IId	46-53"	Heavily iron stained. Slightly compact and plastic	25.8	.24
14090	Transition	53-56"	Friable. Dark gray. Probably mixed with underlying till. Transition horizon	23.0	.24

All of profile highly acid. True III horizon not present.

* Determined by Eric Winters.

TABLE IV

Analytical data for samples from Stage 1 profile

		Chemical data												Optical data	X-ray data	Percent of total	Mineral Composition
Horizon	Fraction	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Ign. loss	Total	Organic matter	H_2O-	H_2O+	SiO_2/R_2O_3				
Ia	R															77.9	Quartz 75%; amorphous silica 10%; feldspar 5%; Fe-Mg minerals 5%; white mica 5%; limonite 2%
	C	50.78	20.43	6.38	1.55	.14	2.17	18.01	99.46	7.18	4.66	6.17	3.52	Aggregates: β=1.577 γ-α=.025	Qs, I, (B?)	8.2	Illite, quartz, beidellite
	F	47.64	21.38	9.42	1.79	.14	1.93	17.74	100.04	3.65	6.09	8.00	2.96	Aggregates: γ=1.582 γ-α=.030;(-);2Vsmall	Qw, B	3.3	Beidellite, quartz
	S	35.71	14.89	7.99	1.29	.43	.76	38.85	99.92	23.22	7.06	8.57	3.03	Aggregates: γ=1.579 γ-α=.030;(-);2Vsmall	B	10.6	Beidellite
IIa	R															68.4	Quartz 80%; amorphous silica tr.; feldspars 10%; Fe-Mgs 5%; white mica 5%; limonite tr.
	C	50.62	22.26	8.42	2.01	.17	1.74	14.08	99.30	3.18	4.48	7.42	3.12	Aggregates: β=1.578 γ-α=.025	Qs, I, (B?)	12.0	Illite, quartz, beidellite
	F	47.42	20.98	10.88	1.92	.20	1.43	16.88	99.71	1.39	7.20	8.29	2.88	Aggregates: γ=1.582 γ-α=.030;(-);2Vsmall	(Q?), B	9.8	Beidellite
	S	46.84	19.82	10.66	1.71	.22	.89	19.95	100.07	3.91	6.30	9.72	2.99	Aggregates: n=1.578 to 1.520; mostly γ=1.578 γ-α=.030;(-);2Vsmall	B	9.8	Beidellite
IVa	R															83	Quartz 65%; feldspars 15%; Fe-Mgs 10%; white mica 5%; carbonates 5%; limonite tr.
	C	50.92	20.43	10.56	2.24	.33	2.15	17.73	99.36		4.34		3.23	Aggregates: β=1.580 γ-α=.025	Qs, I, (B?)	7.1	Illite, quartz, beidellite
	F	47.36	20.41	12.12	2.22	.41	1.56	16.02	100.10		7.25		2.85	Aggregates: γ=1.584 γ-α=.032;(-);2Vsmall	Qw, B	4.9	Beidellite, quartz
	S	48.64	18.95	11.39	1.89	.62	.96	17.42	99.87	2.85	6.06	8.51	2.97	Aggregates: n=1.582 to 1.552; mostly γ=1.582 γ-α=.030;(-);2Vsmall	B	5.0	Beidellite
IVd	R															93	Quartz 50%; feldspars 15%; Fe-Mgs 10%; white mica 10%; carbonates 15%; limonite tr.
	C	45.47	18.98	15.05	2.36	.62	2.40	14.66	99.54		6.82		2.80	Aggregates:β= 1.60 γ-α=.028	Qs, I, (B?)	3.5	Illite, quartz, beidellite, limonite
	F	41.48	16.06	18.63	2.46	.76	1.70	18.21	99.30		9.44		2.55	Aggregates: γ=1.610 γ-α=.030;(-);2Vsmall	Qvw, B	2.5	Beidellite, quartz
	S	42.52	15.68	14.32	2.62	.35	1.34	19.92	96.75		6.18		2.90	Aggregates: γ=1.594 γ-α=.034;(-);2Vsmall	B	1.0	Beidellite

X-ray analyses were made by Prof. P. F. Kerr of Columbia University.

TABLE V

Analytical data for samples from Stage 3 profile

Horizon	Fraction	Chemical data SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Ign. loss	Total	Organic matter	H_2O-	H_2O+	SiO_2/R_2O_3	Optical data	X-ray data	Percent of Total	
Ia	R															84.6	Quartz 75%; amorphous silica 10%; feldspars 5%; Fe-Mg minerals 5%; white mica 5%_; limonite tr.
	C	54.59	20,12	5.78	1,15	,04	2.39	14.77	98.84	4.78	2.98	7.01	3.79	Aggregates: $\beta=1.582$ $\gamma-\alpha=.025$	Qm, I, (B?)	9.3	Illite, quartz, beidellite
	F	48.78	21.33	9.77	1.34	.00	1.31	17.45	99.98	3.92	4.33	9.20	2.96	Aggregates: $\gamma=1.587$ $\gamma-\alpha=.032$;(-);2Vsmall	B	1.5	Beidellite, limonite
	S	26.00	11.56	6.17	.95	.24	.29	53.84	99.05	39.62	6.17	8.05	2.87	Aggregates: $\gamma=1.587$ $\gamma-\alpha=.030$	B	4.6	Beidellite
IIb	R															61.6	Quartz 75%; amorphous silica 5%; feldspars 5%+; Fe-Mg minerals 5%; white mica 5%; limonite 5%.
	C	50.78	22.24	8.62	1.58	.26	1.25	14.54	99.27	1.47	4.13	8.94	3.15	Aggregates: $\gamma=1.582$ $\gamma-\alpha=.030$;(-);2Vsmall	Qw, B	28.8 *	Illite, beidellite, quartz
	F	49.59	22.54	9.70	1.83	.29	1.12	14.86	99.93	1.59	3.64	9.63	2.89	Aggregates: $\gamma=1.586$ $\gamma-\alpha=.032$;(-);2Vsmall	B	4.6	Beidellite
	S	44.62	21.65	8.69	1.49	.39	.59	20.94	98.27	4.26	5.25	11.43	2.88	Aggregates: $n=1.510$ to 1.565; mostly $\gamma=1.565$ $\gamma-\alpha=.030$;(-);2Vsmall	B	5.0	Beidellite
IIIa	R															77.2	Quartz 70%; amorphous silica tr.;feldspars 10%; Fe-Mg minerals 5%+; white mica 5%; limonite 5%.
	C	52.27	20.94	10.67	1.81	.09	1.52	11.77	99.07	.88	2.85	8.04	3.11	Aggregates: $\beta=1.592$ $\gamma-\alpha=.024$	Qw, I, (B?)	15.5 *	Illite, quartz, beidellite
	F	47.05	21.79	11.42	1.88	.08	1.14	13.37	96.73	.90	3.41	9.06	2.96	Aggregates: $\gamma=1.590$ $\gamma-\alpha=.030$;(-);2Vsmall	B	3.6	Beidellite
	S	48.14	20.41	10.31	1.67	.12	.71	17.85	99.21	2.81	5.85	9.19	3.08	Aggregates: $n=1.510$ to. 1.580; mostly $\gamma=1.580$ $\gamma-\alpha=.030$;(-);2Vsmall	B	3.7	Beidellite
IIIc	R															84.6	Quartz 65%; amorphous silica tr.; feldspars 15%; Fe-Mg minerals 10%; white mica 5%+; limonite 5%_.
	C	51.63	21.61	11.05	1.63	.08	1.75	11.16	98.91	..58	2.47	8.11	3.07	Aggregates: $\beta=1.592$ $\gamma-\alpha=.024$	Qm, I, (B?)	11.5	Illite, quartz, beidellite
	F	46.85	22.38	12.07	1.87	.05	1.30	14.78	99.30		4.89		2.63	Aggregates: $\gamma=1.592$ $\gamma-\alpha=.032$;(-);2Vsmall	(Qvw?), B	1.8	Beidellite
	S	46.88	22.50	10.51	1.63	.10	.73	16.09	98.34	1.63	4.44	10.02	2.69	Aggregates: $n=1.545$ to 1.593; mostly $\gamma=1.593$ $\gamma-\alpha=.030$;(-);2Vsmall	B	2.1	Beidellite

X-ray analyses were made by Prof. P. F. Kerr of Columbia University

* Not completely fractionated

TABLE VI

Analytical data for samples from Stage 5 profile

Horizon	Fraction	Chemical data SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Ign. loss	Total	Organic matter	H_2O-	H_2O+	SiO_2/R_2O_3	Optical data	X-ray data	Percent of total	Mineral Composition
Ia	R															88.0	Quartz 75%; amorphous silica 10%; feldspars 5%; Fe-Mg. minerals 5%; white mica tr. limonite 5%
	C	56.77	19.70	5.56	.81	.04	1.74	14.47	99.09	4.82	2.60	7.05	4.13	Aggregates: β=1.572 $\gamma-\alpha$=.024	Qs, I, (B?)	8.3	Illite, quartz, beidellite
	F	47.25	23.29	8.32	1.02	.03	1.28	18.46	99.65		3.78		2.86	Aggregates: γ=1.585; $\gamma-\alpha$=.030;(-);2Vsmall	Qw, B	1.1	Beidellite, quartz
	S	25.45	14.39	4.25	.59	.14	.44	52.75	98.01	36.10	5.96	10.69	2.53	Aggregates:γ=1.595 $\gamma-\alpha$=.030;(-);2Vsmall	B	2.6	Beidellite
IIb	R															58	Quartz 75%; amorphous silica 5%+; feldspars 5%+; Fe-Mg. minerals 5%; white mica 2%; limonite 5%-
	C	51.48	23.41	8.59	1.25	.05	1.27	13.29	99.34	1.04	3.44	8.81	3.07	Aggregates: β=1.585 $\gamma-\alpha$=.030	Qm, I, (B?)	28.6 *	Illite, quartz, beidellite
	F	48.43	24.15	9.40	1.30	.02	.89	15.33	99.42	1.12	4.28	9.93	2.70	Aggregates: γ=1.583 $\gamma-\alpha$=.030;(-);2Vsmall	B	5.9	Beidellite
	S	44.93	21.16	9.91	1.14	.06	.80	21.58	99.58	3.21	6.48	11.89	2.78	Aggregates: n=1.510 to 1.582;mainly γ=1.582 $\gamma-\alpha$=.030;(-);2Vsmall	B	7.5	Beidellite
IId	R															74.2	Quartz 60%; amorphous silica 5%+; feldspars 10% Fe-Mg. minerals 5%+; white mica 5%; limonite 5%
	C	51.82	23.00	8.96	1.40	.07	1.46	12.59	99.30	.59	3.40	8.60	3.00	Aggregates: β=1.585 $\gamma-\alpha$=.030	Qm, I, (B?)	17.5 *	Illite, quartz, beidellite
	F	48.97	23.74	9.40	1.30	.06	1.01	14.76	99.24	.82	4.33	9.61	2.83	Aggregates: γ=1.585 $\gamma-\alpha$=.030;(-);2Vsmall	B	3.4	Beidellite
	S	47.21	21.70	9.91	1.15	.06	.73	19.02	99.78	1.92	6.00	11.10	2.93	Aggregates: n=1.520 to 1.585; mainly γ=1.585 $\gamma-\alpha$=.030;(-);2Vsmall	B	4.9	Beidellite

X-ray analyses were made by Prof. P. F. Kerr of Columbia University

* Not completely fractionated

Fig. 4

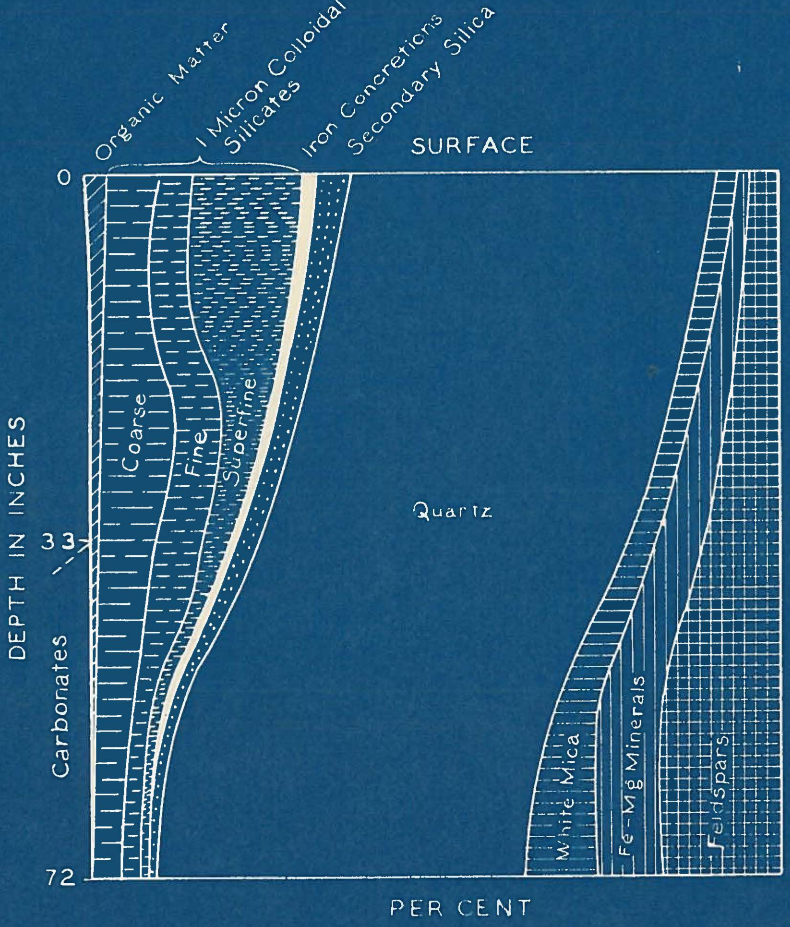
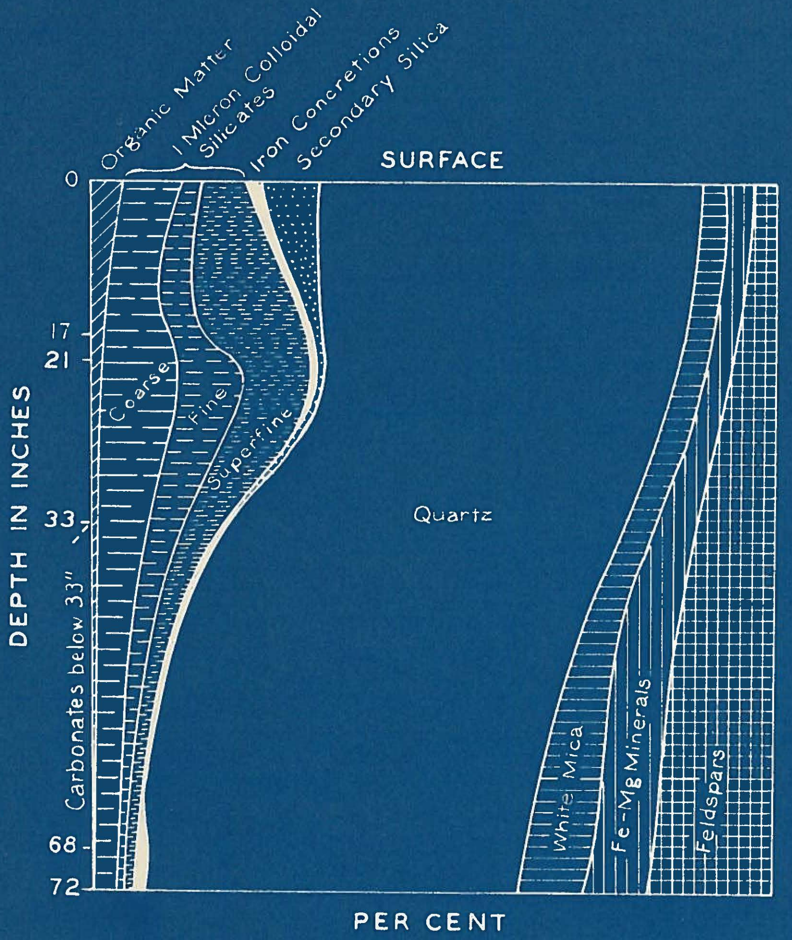
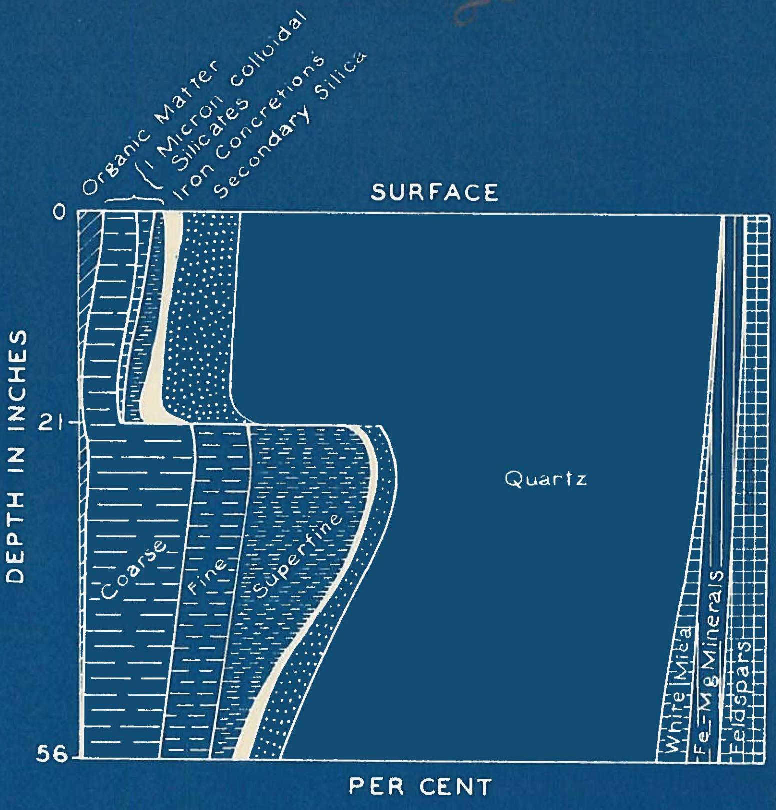

Organic Matter
1 Micron Colloidal Silicates
Iron Concretions
Secondary Silica
SURFACE
0
33
72
DEPTH IN INCHES
Carbonates
Coarse
Fine
Superfine
Quartz
White Mica
Fe-Mg Minerals
Feldspars
PER CENT

Fig 3



Organic Matter
1 Micron Colloidal Silicates
Iron Concretions
Secondary Silica
SURFACE
0
17
21
33
68
72
DEPTH IN INCHES
Carbonates below 33"
Coarse
Fine
Superfine
Quartz
White Mica
Fe-Mg Minerals
Feldspars
PER CENT

Fig 5



Organic Matter
1 Micron colloidal Silicates
Iron Concretions
Secondary Silica
SURFACE
0
21
56
DEPTH IN INCHES
Coarse
Fine
Superfine
Quartz
White Mica
Fe-Mg Minerals
Feldspars
PER CENT

The decrease in aluminum in horizon I was converted to percentage superfine colloid, and this value was added to horizon I. The recast secondary silica values are estimations rather than calculations.

Constitution of the parent loess. - This is shown in the analyses of horizon IV of Table IV and represented by the lowermost portions of Figures 3 and 4. Feldspars of all kinds are present, and they show very small amounts of alteration. The ferro-magnesian group is composed of chloritic material, and amphiboles and pyroxenes showing appreciable chloritic alteration. The white mica is a mixture of muscovite and illite. Beidellite/ and illite with traces of quartz and limonite compose the colloid fractions.

Changes that take place in the weathering of loess. - A comparison of the constitution of the parent loess with that of the uppermost horizons indicate the changes that are taking place in weathering. Carbonates are leached. The beidellite type of clay mineral forms from the white micas, ferro-magnesian minerals, and the feldspars. This is shown in the analytical data by the relative increase of beidellite and decrease of the white micas, ferro-magnesian minerals, and feldspar from the unweathered to weathered material. The analytical data for the identification of beidellite are given in Tables IV to VI.

Beidellite occurs in very small sized particles making up practically all of the Fine and Superfine Colloid Fractions and a considerable part of the Coarse Colloid Fraction. The upper part of

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/ The presence of beidellite in Illinois soils was first determined by V. T. Allen, Am. Soil Survey Bulletin XI, p. 116 (1930).

the weathering profile in which the beidellite develops therefore becomes increasingly more clayey.

The primary minerals show about the following susceptibility to alteration to beidellite in decreasing order: white mica, ferro-magnesian minerals, feldspar. Of the feldspars, the most calcic plagioclases disappear first. Most of the ferro-magnesian minerals show some chloritic alteration, and it cannot be determined how much of this alteration took place before its accumulation in the loess, and, consequently, whether or not chloritic material forms a transition stage in the alteration of these minerals to beidellite.

Much of the iron of the original minerals is retained in the secondary beidellite. In this clay mineral iron and aluminum are isomorphously replaceable and the analysis of beidellite given in Tables IV to VI, show the presence of large amounts of Fe_2O_3. As the iron content of beidellite increases toward the iron end member, nontronite, its indices of refraction also increase. It is noteworthy that the beidellite of the loess has sufficient iron so that its indices of refraction have been raised into the range of the micas. On the basis of optical values alone, therefore, it is commonly impossible to differentiate the beidellite and mica constituents in the colloid fractions of the loess. Some of the iron is liberated, oxidized, and hydrated. It occurs as a pigment in the lower part of the profile and in concretionary pellets throughout the profile.

Much controversy_/ has existed concerning the actual mode of formation of secondary hydrous silicates during weathering. One school has held that the primary minerals break down into their constituent oxides, and that these oxides in a hydrous state recombine into the secondary minerals. The other school considers that hydrolysis and direct change occur from one mineral to the other.

The former school is represented in the field of soils by those who believe that solution of Fe_2O_3, Al_2O_3 and SiO_2 occurs in the surface horizons [and is] followed by downward movement and recombination as silicates in horizon II which is the zone of clay accumulation. Bray has shown, however, that as far as Illinois soils are concerned, the evidence does not support this conclusion. Claypan formation in these soils is due to the mechanical movement of the very fine colloids._/ Furthermore, Bray by chemical studies supported in part by petrographic and X-ray studies by Grim and Kerr respectively has shown that the chemical alteration of mica to beidellite-type colloids is unaccompanied by the formation of any intermediate products._/ The data show successive stages in the alteration of

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_/ Robinson, G. W., Soils, their origin, constitution, and classification: T. Murby & Co., London (1936).

_/ Bray, R. H., A chemical study of soil development in the Peorian loess region of Illinois: Amer. Soil Sur. Assn. Bull. 15, 58-65, 1934.

Bray, R. H., The origin of horizons in claypan soils: Amer. Soil Sur. Assn. Bull. 16, 70-75 (1935).

mica to beidellite accompanied only by the loss of proportionate amounts of K and Mg and a corresponding proportionate increase in base-exchange capacity and water content.

Beidellite forms from the primary minerals in the presence of the carbonate. It should not be considered that leaching and beidellite formation are mutually exclusive, i.e., carbonates are leached before the alteration to beidellite begins. Leaching is more rapid, but both processes go on together. Evidence for this is shown by Stage 1 (Figure 1) in which the parent minerals weathering to form beidellite decrease in relative abundance from the lower part to the upper part of the carbonate portion of the profile. Further there is some evidence to indicate that beidellite formation proceeds most rapidly in the presence of calcite or a general neutral to alkaline environment. Studies of many comparable profiles in varying stages of leaching (of alkalies and alkaline earths (see page) and horizon development show about the same percentage of beidellite in the uppermost 50 inches. The more leached and developed profiles, i.e, those have greater acidity, contain only slightly more clay than the practically neutral (although carbonate free) more youthful profiles. The larger part of the beidellite was apparently formed before any acid weathering occurred. The indication is that beidellite formation proceeds most readily and rapidly in the presence of slightly alkaline to ~~slightly acid~~ neutral conditions.

_/ Bray, R. H., The significance of the weathering loss of K and Mg in soil colloids extracted from Illinois soils. In press. Trans. of the Soil Science Society of America, Vol. I. (In Soil Science, 1936).

Bray, R. H., Chemical and physical changes in soil colloids with advancing development in Illinois soils: Soil Science, 43, pp. 1-14, 1937.

Many of the primary minerals are more siliceous than the beidellite, and as a consequence free silica is liberated in the alteration processes. In the presence of carbonates, this secondary silica is removed in solution by downward seeping waters. In the absence of carbonates, the silica remains behind and may be seen under the microscope as discrete particles of opaline material.

<u>The downward movement and accumulation of beidellite</u>. - One of the outstanding happenings in the weathering of the loess is the downward movement of the beidellite from the surface horizons and its accumulation at slight distances beneath the surface. As illustrated by a comparison of Figures 2 and 4, progressive weathering increases the distance beneath the surface of the zone of accumulation, and the sharpness with which it is separated from the surface horizons. In Stage 5 (Fig. 3) the uppermost horizon has very little remaining beidellite, and the zone of accumulation is encountered abruptly. The lower limit of the zone of accumulation is not sharp.

Downward movement of the beidellite starts with the development of the mineral in the uppermost horizons. In the earliest stage of weathering studied, Fig. 1, appreciable movement has already taken place. It has been shown that the beidellite is moved downward in colloidal suspension and not in solution. The causes of the accumulation in the shallow subsurface zone of beidellite from the uppermost horizons and the beidellite found in the zone itself has been discussed by Bray.[/]

[/] Bray, R. H., The origin of horizons in claypan soils: Bull. Am. Soil Survey Assoc. 16, pp. 70-75 (1935).

Since the beidellite content of the weathering profile is essentially the clay content, the downward movement of beidellite causes the uppermost horizons to become loose, silty, and easily transported by the wind. Likewise, the zone of accumulation becomes very clayey, dense, compact, and impervious. It is commonly spoken of in soil science as a clay pan horizon.

Characteristics of the well weathered loess section. - In addition to the sharp accumulation of beidellite, Fig. 5 illustrates also the other changes taking place as weathering progresses. The white micas, ferro-magnesian minerals, and feldspars are disappearing from the upper part of the profile in about that order. Amorphous silica produced by the alteration of some of the primary minerals is accumulating in the uppermost horizons. As a consequence of the removal of the secondary aluminous mineral (beidellite) and the remaining of the silica, the uppermost horizons become~~s~~ increasingly richer in SiO_2. In horizons Ib and c, the content of SiO_2 of the whole material reaches over 80 per cent. Such material has a gray ashy appearance.

Increased weathering tends to decrease the amount of alkalies and alkaline earths in the profile as shown by the values for the whole soil material which are not included in the tables. Beidellite possesses high base exchange capacity. It can, therefore, retain temporarily as exchangeable bases the alkalies and alkaline earths originally possessed by the primary minerals. The alkalies and alkaline earths are used by plants, and are eventually removed in solution by ground water. As these ions are removed, they are replaced by hydrogen as the exchangeable ion, and the material becomes acidic.

The decrease in potassium content is due mainly to the alteration of the mica to beidellite which is not a potassium mineral. The loss of potash due to the weathering of potash feldspars is slow because of the weathering resistance of the potash feldspars. The magnesium and calcium in the carbonate-free soil are reduced at varying rates by weathering. In horizons I and II of the less weathered soils over 50 per cent of the calcium present may be exchangeable. A much smaller proportion of the total magnesium is exchangeable._/ In the more advanced stages of weathering Bray and DeTurk have shown that the replaceable magnesium can actually exceed the replaceable calcium in terms of milliequivalents per 100 grams._/ This has apparently resulted from the fact that the calcium minerals are less stable and yield no stable secondary forms while the magnesium minerals are more resistant and in addition magnesium may be retained as an essential non-replaceable base in the beidellite._/

_/ Catherwood, M. P., and DeTurk, E. E., The relation of soil type to the exchangeable calcium and magnesium in some Illinois soils: J. Am. Soc. Agron. 20, pp. 657-678 (1928).

_/ Bray, R. H., and DeTurk, E. E., Chemical aspects of some Illinois soils as related to their genesis and morphology: Int. Cong. Soil. Sci., 5, pp. 118-131 (1932).

_/ Bray, R. H., Ibid.

The source of supply of replaceable magnesium during later stages of weathering is therefore greater than the calcium.

Alteration of beidellite. - Long continued weathering tends to cause the breakdown of the beidellite into its constituent oxides. The iron and alumina so released together with iron yielded in the disintegration of the primary minerals tend to aggregate in small rounded pellets. These pellets are concentrated at the top of the horizon of beidellite concentration. The silica so produced is mainly amorphous and is concentrated above the zone of beidellite concentration or occurs as a thin white coating of fractures and openings in the beidellite horizon. Some of the secondary silica is not amorphous and occurs as marginal additions to quartz-grains in crystallographic continuity with them.

Based on calculations involving the disappearance of the potassium and magnesium during weathering and the appearance of increased base-exchange capacity, Bray[1] has suggested that there are two slightly varying types of beidellite materials and that these types are successively passed through in its break down to constituent oxides.

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[1] Bray, R. H., Idem. 1937.

Weathering of loess under conditions of good subsurface drainage

The following discussion is based on the study of the analytical data of a well drained profile as presented in Tables VII and VIII , and also on some unpublished work of DeTurk and Bray.

Under conditions of good subsurface drainage the same general weathering effects are produced as under conditions of poor subsurface drainage. Under the former conditions, however, less of the secondary fine colloidal material (beidellite) is present in the profile, i.e., more is carried away by ground water. Also, the beidellite tends to be more uniformly distributed throughout the profile rather than highly concentrated in a clay pan horizon. The free oxides and hydroxides of iron do not have as much tendency to occur in aggregate. They are fairly uniformly distributed throughout the profile and more intimately associated with the colloidal material. It is noteworthy_/ that the iron hydroxides tend to be concentrated in the Fine Colloid Fraction (.1-.06 microns). The effect of this association of the iron hydroxide and colloid material is to render the whole weathered material relatively less plastic, to lower the base-exchange capacity, and to increase the particle size within the colloid size range. As a result the whole material is relatively more resistant to erosion and has a reddish color.

Another feature connected with the well drained conditions which will be brought out in a later paper by DeTurk and Bray is

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_/ Grim, R. E., and Bray, R. H., The constitution of various ceramic clays: J. Am. Cer. Soc. 19, pp. 307-315 (1936).

TABLE VII

Description of profile developed under conditions of good subsurface drainage

Type: Number 14, Ava silt loam; immature phase*(U. S. Bureau - Memphis).

Location: T 6 N, R 1 E, Section 16, SW. 1/4 NW. 40. Fayette County.

Topography: Rolling.

Sampled by: E. A. Norton and R. H. Bray. 10-12-28.

Number	Horizon	Depth	Description	Colloids Percent 1 micron	Organic carbon percent
13051	Ia	0-4 "	Yellowish brown, very friable silt loam	6.4	2.42
13052	Ib	4-11"	Laminated, reddish yellow friable silt loam	9.3	.97
13053	Transition	11-15"		12.3	.56
13054	IIa	15-20"	Slightly compact, non-plastic silt loam. Particles 1/4 to 1/2 inch, coated reddish-yellow, bright yellow when rubbed	16.4	.37
13055	IIb	20-34	Similar to IIa	27.5	.25
13056	IIc	34-42	Particle structure becoming indefinite. Very friable	24.9	.18
13057	Transition	42-55	Structureless, friable silt loam on weathered drift	20.5	.14

* Less mature than the majority of upland soils in Fayette County due to local influence of nearness to river.

TABLE VIII

Analytical data for samples from profile developed under conditions of good subsurface drainage

		Chemical data															
Horizon	Fraction	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Ign. loss	Total	Organic matter	H_2O-	H_2O+	SiO_2/R_2O_3	Optical data	X-ray data	Percent of total	
	R															87	
Ia	C	50.76	21.18	8.72	1.42	.12	3.16	13.25	99.61	3.98	3.93	6.34	3.22			6	
	F	48.54	19.68	11.90	1.58	.12	1.29	18.99	102.10	3.67	5.46	9.86	3.02			3	
	S	19.04	12.07	5.33	.64	.44	.77	60.79	99.08	40.07	6.74	13.98	2.09			4	
	R															67	
IIb	C	49.87	21.97	9.96	1.55	.00	2.23	13.71	99.29	.78	5.54	7.39	2.99	Aggregates: β=1.580 γ-α = .030	Qvw, B	15	Illite, beidellite, quartz
	F	45.66	20.23	11.42	1.68	.11	1.74	17.89	98.73	.78	8.32	8.79	2.82	Aggregates: γ=1.586 γ-α=.030;(-);2Vsmall	B	11	Beidellite
	S	43.30	21.65	9.80	1.39	.26	.96	22.47	99.83	3.31	8.03	11.13	2.63	Aggregates: n=1.575 to 1.530; mostly γ=1.575 γ-α=.030;2Vsmall;(-)	B	7	Beidellite
	R															84	
Transition to till	C	47.39	22.22	11.31	1.67	.09	1.94	15.07	99.69	.83	6.48	7.76	2.73			9	
	F	45.69	17.10	13.14	1.60	.12	1.42	16.71	95.78	1.39	6.62	8.70	3.04			5	
	S	40.70	21.20	9.25	1.30	.36	1.20	25.55	99.56	8.57	6.11	10.87	2.55			2	

X-ray analyses were made by Prof. P. F. Kerr of Columbia University that under these conditions the chemical alteration or decomposition of the primary and secondary silicates is less rapid than under conditions of poor drainage. This is especially true for the potash minerals. It has already been indicated that beidellite forms most rapidly in a neutral or alkaline environment. Under conditions of good drainage the calcite is rapidly leached and the bases produced by disintegration are removed more rapidly than in the case of the poorly drained profile. As a consequence an acid environment is produced before as much silicate disintegration has taken place, and thereafter the rate of such disintegration is reduced. Further under conditions of good drainage there are longer periods during which the loess is dry which would retard the rate of chemical alteration.

It is recognized that increased surface erosion under conditions of good drainage by removing colloidal alteration products would cause relatively larger proportions of unweathered material to be in the profile. Considerable study_/ of soil profile data has shown that the difference in relative abundance of constituents in well drained and poorly drained profiles can only in part be attributed to surface erosion.

_/ DeTurk, E. E., and Bray, R. H., Unpublished data.

Influence of variation of composition and of vegetation on the weathering of loess

In general the composition of the loess in Illinois has not been found to vary sufficiently to materially influence the weathering effects. The increased content of coarser material near the sources of the loess has caused profiles development in these areas with relatively lower contents of colloidal material.

The weathering effects are not changed in any important way by variations in the character of the surface vegetation. In the early stage of weathering colloidal movement is somewhat more rapid under timber than under prairie surface growth. In more mature stages the profiles are very similar in all respects except organic matter content. Prairie vegetation permits the accumulation of a larger amount of organic material in the surface soil. Accompanying this higher organic matter content is a higher content of the superfine colloid fraction especially in the younger soils. As the superfine colloid decreases in amount with the development of Horizon I, the organic matter content decreases also. The factors determining the apparent correlation between the superfine colloid and organic matter are not fully understood.

Discussion and summary of the weathering of loess in Illinois

Of prime importance in the weathering of loess is the formation of beidellite from the primary aluminous minerals. This secondary silicate exists in particles less than one micron in diameter so that its development causes the loess to become more clayey. The high base-exchange capacity of beidellite permits the alkalies and alkaline earths to be temporarily retained in the weathering profile. These bases are replaced gradually by hydrogen ions and the material gradually changes from basic to acidic.

Leaching of the carbonates and oxidation of the iron take place contemporaneously with the formation of beidellite although at a more rapid rate. Evidence is presented to indicate that beidellite forms most rapidly in a neutral to alkaline environment, ~~and in the presence of carbonates~~. In the breakdown of the original minerals free silica is produced which remains in place in the weathering profile after the carbonates have been removed.

The beidellite migrates downward from the uppermost horizon, and when the topography is flat and, as a consequence, subsurface drainage is poor, it accumulates a short distance beneath the surface forming a dense impervious zone. The uppermost horizon thereby becomes increasingly silty.

Under long continued weathering the beidellite is broken down into its component oxides. Under conditions of poor drainage, the aluminum and iron so produced, together with some of the iron liberated in the weathering of primary minerals, aggregate into small pellets.

The removal of the beidellite following the disintegration of the primary silicates from the uppermost horizons increases the relative abundance of quartz. The total silica content of these horizons is further increased by the production of secondary silica in the disintegration of some of the primary silicates and also of the beidellite. Since this silica is not removed from the profile after the carbonate is leached, silica is concentrated in the uppermost horizons of the loess.

Under conditions of good surface drainage, the beidellite tends to develop less rapidly and not to be concentrated in a clay pan horizon. Also, the iron hydroxide is uniformly mixed with the beidellite rather than concentrated in pellets. As a result of the latter characteristic the whole weathered zone has a reddish color and somewhat different physical properties from the material weathered under conditions of poor drainage.

Textural variations of loess in Illinois exert no pronounced effect on the alteration products. Where the vegetation cover is the timber type rather than the prairie type, there is a relative increase in the rate of development of the profile in the initial stages of weathering.

Kaolinite is not present at any time in the weathering of the loess. This must be emphasized in view of the reluctance of geologists and others to part with the ancient erroneous idea that kaolinite occurr~~ed~~s in all clay and in all clayey weathering products.