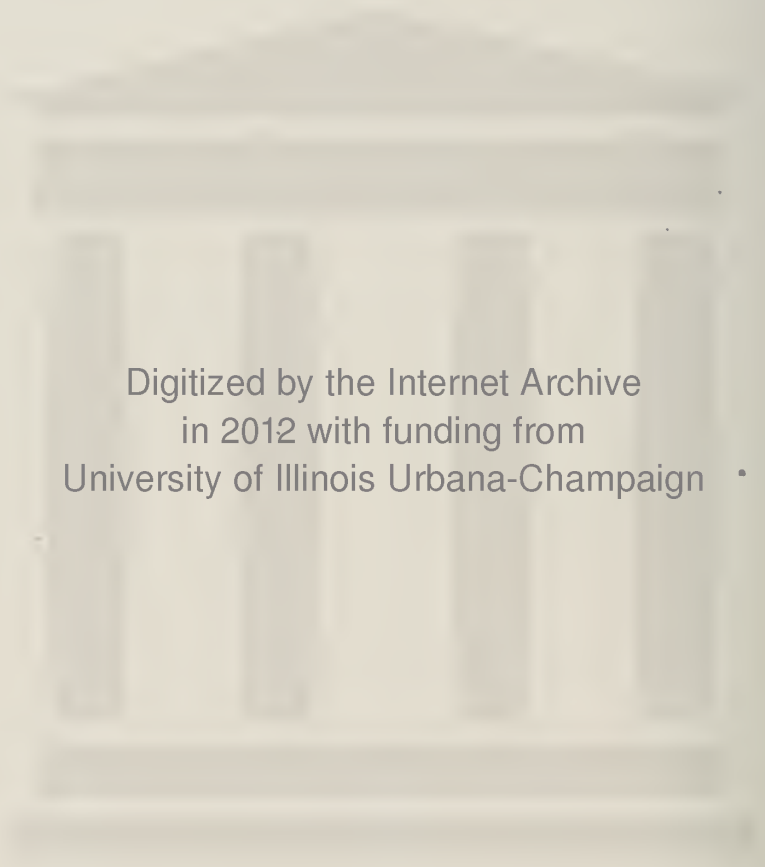


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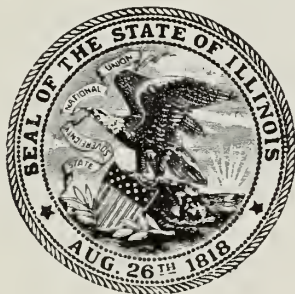
STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
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STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*

REPORT OF INVESTIGATIONS—NO. 20

WEATHERED ZONES OF THE DRIFT-SHEETS OF ILLINOIS

BY M. M. LEIGHTON AND PAUL MACCLINTOCK

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WEATHERED ZONES OF THE DRIFT-SHEETS OF ILLINOIS¹

MORRIS M. LEIGHTON AND PAUL MACCLINTOCK

ABSTRACT

A study of the weathered zones of the various drift-sheets of Illinois reveals that they consistently comprise four subdivisions, regardless of topographic or vegetative environment, but that the zones nevertheless show characteristic responses to topographic position and to drainage conditions. In well-drained areas the *silttil profile* has developed, in poorly drained areas the *gumbotil profile* has developed, and in partially drained areas the *mesotil profile* has developed.

The Wisconsin and Iowan drift-sheets show immature profiles but the Illinoian and older drift-sheets show, respectively, early-mature to mature profiles. It seems probable that silttil profiles of one area may be correlated with gumbotil profiles of another area.

In the older drift-sheets where erosion has worked headward into a broad flat area, the gumbotil profile of weathering may show in its upper portion the beginning of a second profile due to the newer and better drainage conditions. "Fossil" weathering profiles buried beneath later deposits reveal the conditions that prevailed during the interglacial stages in which they were developed.

INTRODUCTION

When a geologist observes weathered glacial drift under unweathered drift, he appreciates the importance of ascertaining whether the alteration was accomplished by percolating ground waters acting along a more porous bed or by surface weathering during a period of time when the top of the lower drift was exposed. If the evidence shows that the alteration was accomplished by surficial weathering, the question then is how complete is the preserved record and how detailed an interglacial history can be read from it.

In the case of an incomplete record it is important to determine in what way and degree it is incomplete, in order that the available record may be properly evaluated. It is also equally important to determine, in the case of a complete record, the topographic and climatic conditions under which the weathering took place, the duration of the period of weathering, and whether or not topographic changes of consequence are reflected in the record.

Much was done by the early workers in determining what chemical changes had taken place in the weathered zones of the various

¹ *Illinois State Geological Survey Studies.*

glacial drift sheets, but not until Kay¹ pointed out that the gumbotil on the Kansan drift of southern Iowa was derived from normal glacial till by advanced chemical weathering under broad poorly drained flats did geologists give much attention to the topographic implications of weathered zones. This was a distinct step of progress. Recently the interpretation of weathered zones has been carried farther to include the recognition of an equally significant product resulting from weathering under well-drained conditions. It is also now recognized that all weathered zones on the glacial drift sheets of the Mississippi Valley states have fundamental and consistent subdivisions, each of which reflects the environment of weathering conditions. By recognizing these subdivisions it is possible to determine the completeness of the record more satisfactorily than has hitherto been possible and to determine what, if any, topographic changes occurred during the period of weathering.

PURPOSE OF THE PRESENT ARTICLE

This article summarizes the results of a detailed study of the weathered zones of drift-sheets, from the standpoint of their structures, their responses to different topographic situations, their stages of development with age, and their modifications under a new cycle of physiographic conditions.

For the benefit of the reader who may not be active in Pleistocene studies, the divisions of the North American glacial epoch are here given as follows:

GLACIAL AND INTERGLACIAL STAGES OF THE PLEISTOCENE EPOCH

- Wisconsin glacial stage
- Peorian interglacial stage
- Iowan glacial stage
- Sangamon interglacial stage
- Illinoian glacial stage
- Yarmouth interglacial stage
- Kansan glacial stage
- Aftonian interglacial stage
- Nebraskan glacial stage (oldest known)

¹ G. F. Kay, "Gumbotil, a New Term in Pleistocene Geology" *Science*, New Series, Vol. XLIV (1916), pp. 637-38; G. F. Kay, and J. N. Pearce, "The Origin of Gumbotil," *Jour. Geol.*, Vol. XXVIII (1920), pp. 89-125.

CONCEPTION AND PERSONNEL OF THE PRESENT INVESTIGATION

In 1914, the late Dr. K. D. Glinka, director of the Agricultural Institute of Leningrad, recognized a twofold division of the soil above what he termed parent material and described how the characteristic features of these divisions persist or change consistently in response to the climate, regardless of the character of the parent-material.¹ Later Dr. C. F. Marbut, of the United States Department of Agriculture, visited Russia and brought back the germinal thought behind Glinka's philosophy. Glinka assigned letters to his two divisions of the soil: the letter A to the eluvial surficial material from which, either by chemical or mechanical (probably both) means, more or less material has been removed; the letter B to the illuvial subzone into which the clayey material has been carried chemically or mechanically; and C to the parent-material beneath. His A includes the humus-charged silty material as well as any non-humus silty material that lies above the denser, more compact, and plastic B.

When Marbut in 1923 gave his series of splendid lectures at the University of Illinois on "The Great Soil Groups of the United States," the first-named author of this article conceived that a study of the characteristics of our modern soils and weathered zones, as they are developed on drift-sheets and loesses of different ages, under different topographic situations and vegetal coverings, should yield much information of value in interpreting more completely our fossil interglacial zones.

The study was soon undertaken by both authors, who were working on the Pleistocene deposits of Illinois, and after four years of study the present article is offered. During the study the authors have enjoyed the active collaboration of the state soil specialists of Illinois, Dr. R. S. Smith and Mr. E. A. Norton, who approached the problem from the standpoint of soil genesis and directed attention especially, and with great helpfulness, to the detailed characters of the soil and immediate subsoil materials. The authors, however, have been interested primarily in the geological aspects of the weath-

¹ D. Glinka, "Die Typen der Bodenbildung, ihre Klassifikation und geographische Verbreitung" (Berlin: Verlag Gebrüder Borntraeger, 1914).

ered zones taken as a whole, and assume responsibility for the geological classification, interpretations, and bearings here presented.

Although there are some climatic differences between northern and southern Illinois and some resultant differences in weathered zones on drift of the same age, these are not considered in the present discussion because they do not materially affect or alter the features mentioned.

SUBDIVISIONS OF THE WEATHERED ZONE

The weathered zone on the Illinoian drift-sheet in southern Illinois has reached a mature stage of development and is differentiated into clearly recognizable subdivisions, subdivisions that are much less clearly shown on the younger drift-sheets. Hence, the description of these subdivisions is largely based on the Illinoian weathered zone, although confirmed and extended by examinations of the weathered zones on the Kansan and Nebraskan drifts.

The weathered zone on the Illinoian and older drift-sheets, wherever preserved and exposed in a vertical section, is invariably divisible into four easily recognized horizons under all topographic situations except those in which erosion has cut away the upper ones (Fig. 1). These are as follows:

SUBDIVISIONS OF THE WEATHERED ZONE

Horizon 1: the surficial soil

Horizon 2: chemically decomposed till,* composed chiefly of alteration products and resistant constituents of the original till, and strikingly unlike the original till

Horizon 3: leached and oxidized till, otherwise but little altered

Horizon 4: oxidized till, but unleached and otherwise unaltered

* The term till is here used for unstratified glacial drift.

The unweathered till below may be referred to as horizon 5. The succession of horizons 1, 2, 3, and 4, as seen in an exposure, constitutes what is here designated as the "profile of weathering," which is a vertical section of the zone of weathering.

Horizon 1, the surficial soil, is silty and has characteristic structures, textures, and colors, for a given set of climatic, topographic, vegetative, and age factors, and, so far as the primary inorganic constituents are concerned, is probably the most thoroughly weathered of all the divisions. The authors are not yet ready to under-

take an adequate discussion of these characteristics under the various sets of conditions. The lower limit of horizon 1 is placed at the top of the vertical columnar structure of horizon 2, wherever this

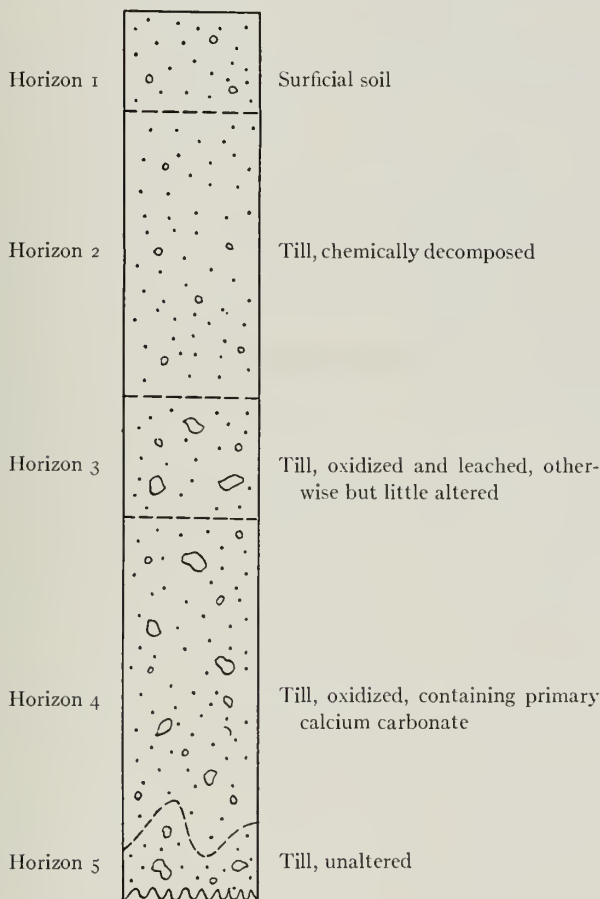


FIG. 1.—Generalized section showing maturely weathered zone in glacial till

structure is developed, but in some cases the columnar structure is absent, even in maturely weathered zones, and the division between 1 and 2 is indeterminate for practical purposes.

No attention is here given to abnormally thick deposits of surficial humus materials which accumulate in depressions by wash from

bordering slopes, to fossiliferous marls which form on lowlands, to peat-beds, or to other similarly accumulated soil material.

That there is some wind-blown dust or loess in almost every horizon 1 seems probable, but it is apparently very minor indeed in horizon 1 of the Illinoian drift, as shown by the remarkably consistent thickness of this horizon over broad areas, even to the very bluffs of the major valleys. Most of the loess was deposited more rapidly than leaching occurred, as shown by the calcareous zones, and then at the close of the loess-forming epochs weathering set in and changed their upper portions into weathered zones, giving consistent profiles within the superposed material. But in those areas where the mantle of loess is very thin, and particularly on the "crayfish flats" of southern Illinois, the loess may be not only much weathered but also modified in texture by the introduction of pebbles from the drift below by crayfish and other agencies. In the area mentioned a thin deposit, much weathered and apparently reworked, overlies the Illinoian weathered zone. If it is not a second-cycle weathered zone (see p. 40) modifying the upper part of the primary profile of the Illinoian drift, it is probably modified loess.

Horizon 2 is composed of the residue from, and some of the material produced by, oxidation, leaching, and advanced chemical decomposition. The pebbles are few and small, most of them less than $\frac{3}{4}$ inch in diameter, although occasionally a pebble $1\frac{1}{2}$ inches in diameter or larger may be found. They consist of chert, quartz, quartzite, jasper, and dense greenstone, and rarely of granite, diorite, gabbro, or other coarse-grained igneous rocks. Limestone pebbles and primary calcium carbonate are entirely lacking in the matrix.

The difference between this horizon and the unaltered till below is so great from the standpoint of lithology, texture, and chemical composition that one would scarcely suspect that the material was ever normal till, were it not for the transition downward into unmistakable till. Indeed, where horizon 2 rests on bedrock, there may be difficulty in finding igneous pebbles to prove that the deposit was originally till.

Horizon 3 is more characteristically till-like. It has suffered only oxidation and leaching and is the site of concentration of sec-

ondary iron oxide from above. The pebbles have a larger range in size than those in horizon 2, they are more dominantly of the arkosic type, and they include granite, diorite, gabbro, and other coarse-grained rocks which are firm except in the zone of transition from 2 to 3. But this horizon differs from the underlying horizon 4 in that it has no limestone pebbles or finely comminuted limestone flour, these materials having been dissolved. Rarely a remnant of a large limestone boulder is found, which, by reason of its size, has not been entirely leached away.

Horizon 4 has a normal content of primary calcium carbonate, and the limestone pebbles are firm except in the few inches of transition from 3, where they are etched and softened. It commonly contains concretions of calcium carbonate. The material in this horizon differs mainly from the material in horizon 5 in that it is oxidized. The oxidized zone grades downward into the unoxidized and unaltered parent-material.

ORIGIN OF THE HORIZONS

ORIGINAL COMPOSITION OF THE TILL

Only a general statement can be made here regarding the origin of the four horizons of weathering. Before weathering set in, the till of the drifts in the Mississippi Valley states was composed of a more or less compact or stiff, pebbly, calcareous clay, containing a greater or lesser number of boulders, according to the locality. The fine particles of the matrix as well as the pebbles and cobbles comprised a variety of material, sedimentary, igneous, and metamorphic, intimately mixed. The sedimentary material consisted chiefly of limestone, shale, sandstone, and chert; the igneous, of granite, diorite, gabbro, etc., and their porphyritic and fine grained equivalents; the metamorphic, of schist, gneiss, quartzite, argillite, vein quartz, jasper, greenstones, etc. The composition of the drift was thus calcareous and arkosic, including some very resistant types of rock; hence the chemical weathering that followed was necessarily selective.

WEATHERING AGENTS AND PROCESSES

With the change from a cold to a warm climate and the disappearance of the ice sheet, vegetation and animal life reinvaded the new drift area, and the organic, physical, and chemical weathering

processes set in, beginning at the surface and in the upper part and working downward. Surface and near-surface activity of roots, burrowing animals, wetting and drying, freezing and thawing, etc., as well as chemical processes, began promptly, and in time gave rise to horizon 1, of characteristic texture and structure.

Some of the surface and near-surface processes became ineffective with depth but chemical weathering proceeded, the different processes at different rates—*oxidation* and *hydration* the most rapidly; *leaching* of the limestone pebbles and calcareous matrix somewhat less rapidly; the *disassociation* or *decomposition* of the coarse-grained silicates still less rapidly; and, finally, for the oldest drifts, destruction of the more resistant fine-grained silicates and the slow solution of the cherts and quartzites. Owing to the different rates at which these four processes operate, the profile on the Illinoian and older drifts came in time to have the four horizons with thin transition zones between them.¹

OXIDATION, HYDRATION, AND LEACHING

Ignoring the development of the surficial humus layer, the first zone to be formed was the oxidized and hydrated zone, the oxidation and hydration processes beginning virtually at the surface and working downward. The second zone was the leached zone. Leaching began simultaneously with oxidation but operated more slowly so that the leached zone proceeded downward as a second wave of alteration, following in the train of oxidation. There is considerable misunderstanding regarding the behavior of the leaching process in compact till. It is active only in the transition zone of from 1 to 4 inches that separates the leached zone above from the calcareous zone below. In this transition zone the limestone pebbles are etched and softened; above it the limestone pebbles and calcareous particles are gone; below it the limestone pebbles are intact, unetched, and firm, and the matrix has its normal content of primary calcium carbonate. Apparently ground water percolates very slowly through

¹ Since this article was written it has come to our attention that the different rates at which these several chemical processes have operated and the different depths to which they have progressed in the Kansan drift of Iowa and Minnesota were noted and described over twenty years ago by R. T. Chamberlin. These studies were not followed up and the data have remained unpublished in the original note books now in possession of the United States Geological Survey.

compact till and becomes saturated with lime carbonate within a few inches. Therefore, the leached zone deepens as this zone of active solution descends. Below the leached zone, the concretions and veins of lime carbonate found in many exposures probably represent the precipitation of lime carbonate from the descending waters, the amount precipitated being only that which the waters could not hold in solution.

In gravel the transition zone is apt to be somewhat thicker, depending on the size of its coarse aggregate, the amount and size of voids, and whether or not the position of the gravel permits free circulation of ground water. The inference is that ground water percolates farther in gravel, as a rule, than in till before it becomes saturated with lime carbonate. The anomaly of limestone boulders in an otherwise leached zone is due to the greater volume of calcium carbonate in its mass than in the same mass of till, its greater compactness, and the low ratio between the surface exposed and the volume of the mass.

CHEMICAL DECOMPOSITION OF THE SILICATES

Promptly upon the leaching of the calcium carbonate (and calcium magnesium carbonate), the carbonic acid and other acids of the downcoming ground water begin their attack upon the silicates. Thus the disassociation or chemical decomposition is a third wave of alteration that follows in the train of leaching. Commonly the zone of transition from the decomposed to the undecomposed coarse-grained silicates is no more than 6 or 8 inches thick. Above the transition zone there are few or no granites and diorites; in the transition zone the granites and diorites are soft, so much so as to be crushed in the hand, and below it they are firm. This wave of alteration lags behind the wave of leaching by from 1 to 2 feet in the Illinoian drift, and somewhat more in the Kansan drift. This would seem to indicate that chemical decomposition begins promptly at the surface upon the removal of the lime carbonate but that it proceeds more slowly than leaching, and the interval between the two increases with time.

The upper part of the zone of silicate decomposition is affected and modified, as noted above, by plant and animal organisms and

by the physical and chemical agencies and processes that operate at and just below the surface, thus creating the surficial soil layer or horizon 1.

CONCENTRATION OF IRON OXIDE

Just beneath the zone of silicate alteration there is a concentrate of iron oxide, in some places showing as a band or bands of rusty color, in others as a belt of concretions ranging in size from pellets to as large as 3 inches or more in diameter. These concretions have a considerable range of hardness, from soft clay having concentric circles, to hard clay ironstones. Distinction is to be made between these forms of iron-oxide concentration and the "pipe-stems" which develop around roots of vegetation and the pellets deposited by the action of soil bacteria.

The almost invariable occurrence of this "layer" of concentrated iron oxide at the base of the horizon of silicate alteration shows that it is constantly being dissolved and reprecipitated, migrating downward as the horizon of active alteration descends.

ILLUVIATION

Attention has been focused by many pedologists on the common presence of a plastic heavy subsoil zone in partially drained profiles which they account for by illuviation. This is not to be confused with the gumbotil which is largely the product of decomposition *in situ* in poorly drained areas. Wisconsin drift and the younger loesses commonly show an illuviated zone within slightly or partially decomposed silicate materials. Older drift, however, in partially drained profiles commonly shows an illuviated zone at the top of the maturely decomposed horizon 2, in which case it is the B horizon of the pedologists. It has also been found, however, *within* the body of horizon 2 and even *below* it. The authors, therefore, are led to the conclusion that illuviation is an *attendant* process rather than a *fundamental* one in the development of weathered zones, that it is an expression of certain physicochemical conditions which are likely to prevail near the surface but may also occur at lower levels. In so far as it appears commonly at the top of horizon 2, the designation B of the pedologists has its place in the present classification.

FACTORS DETERMINING THE RATE OF DEVELOPMENT
OF SOIL PROFILES

Geographically the rates at which these changes take place are affected by the length of season when the ground is frost-free, the amount of water which enters the ground, the amount of water which is returned to the surface by capillarity, the rate at which the water passes downward, the temperature of the waters, the chemical composition of the material, the degree of comminution of the materials, the kind and character of the vegetation, the amount of carbon dioxide and other acid-making substances which the water obtains from the air and the humus-charged layer, the amount of oxygen lost by the water in passing through the humus and other deoxidizing material, the action of soil bacteria, and other agencies, processes, and conditions which cannot be discussed here.

The thickness of the zone of weathered materials also depends not only on the rate of weathering and the composition of the drift, especially its limestone content, but on the rate of removal of the calcium carbonate and also on the depth at which stagnant water occurs in the ground.

At most places the rate of weathering decreases with depth. The materials become more compact, some of the carbonic and other acids are neutralized in their alteration of silicates so that as time passes there is a lower and lower concentration of acid available for leaching at lower depths, and some of the oxygen of the waters is used in oxidizing the ferrous iron that is set free in the alteration of the silicates. The precipitation of lime carbonate in the calcareous zone, derived by leaching above, also adds that much more calcareous material to be leached again later.

When a new drift-sheet or a new loess deposit is superimposed and if it has sufficient thickness to cause a marked change in the chemical action of the descending waters, the development of the former zone of weathering stops and it becomes a "fossil" weathered zone, subject, however, to secondary changes.

FACTORS DETERMINING THE TYPE OF PROFILE DEVELOPED

TOPOGRAPHIC SITUATION

The foregoing characteristics hold, whatever the topographic situation, except on steep slopes where erosion proceeds as rapidly

as weathering, and possibly except beneath swamps and bogs where there has been little or no downward circulation of ground water. There are important ways, however, in which the factor of topographic situation exerts its influence on the *moisture conditions* of subsurface materials and leaves its characteristic impress on weathered zones that develop under these conditions, provided there has been adequate time.



FIG. 2.—Flat, poorly drained land underlain by gumbotil developed on Illinoian drift, Marion County, Illinois (photo by MacClintock).

Broad, flat, poorly drained areas.—In the Illinoian drift area of southern and western Illinois, there are broad tracts of flat, poorly drained upland (Fig. 2). The profiles of weathering under these areas show an abnormally thick horizon 1; a gray to brownish gray, tenacious, plastic gumbotil in horizon 2, which when dry shows distinct vertical columnar structure; and a banded or spotted iron zone at the top of a thin horizon 3.

The gumbotil contains markedly fewer pebbles of much smaller average size and more pebbles of the resistant siliceous types than

does the till of the lower horizons, and it is clearly a product of advanced weathering. Its topographic position on the highest broad

EXPOSURE SHOWING PROFILE DEVELOPED ON POORLY DRAINED
ILLINOIAN DRIFT IN EFFINGHAM COUNTY, ILLINOIS

	THICKNESS	
	Feet	Inches
Soil and loess, containing a few scattered pebbles apparently introduced by organic agencies; upper 14 inches friable, the remainder compact and plastic; the lowest 9 inches may be a lower loess.....	2	10
Illinoian till:		
Horizon 1. Fossil soil:		
A. Soil, brownish black with red-brown spots, friable, non-plastic silt, containing sand and small pebbles.....	..	7
B. Silt, dirty gray, slightly more plastic than A, contains streaks of gray and reddish brown.....	..	12
Horizon 2. Gumbotil:		
A. Clay, sandy, pebbly, dark gray, streaked with rusty brown, plastic, compact, containing more pebbles than Horizon 1.....	1	8
B. Clay, very sandy, pebbly, light gray, plastic but not very compact; pebbles are distinctly larger near base, matrix splotted with yellowish brown and more so near base, some streaks of darker gray.....	2	6
Horizon 3. Till, leached and oxidized, otherwise but little altered:		
Till, sandy, pebbly, silty; non-calcareous, reddish brown, slightly iron-cemented, friable, non-plastic; includes both large and small veins of gray material, large veins more sandy than the general matrix, some faces black-coated ..		6
Horizon 4. Till, oxidized, containing primary calcium carbonate:		
A. Till, calcareous, brown, iron-cemented like horizon 3, some horizontal lenses of sand.....	1	8
B. Till, calcareous, oxidized, friable, compact, joint faces coated drab-gray, fresh surfaces grayish yellow.....	4	
Horizon 5. Unaltered till:		
Till, unweathered, blue-gray.....	6-8	

uplands and its gradation below into typical till shows that it was derived from till and not from slope-wash. The same profile has been developed beneath broad flat uplands on the Illinoian drift of southeastern Iowa and southwestern Ohio.

Similarly the weathering profiles in the flat, tabular divides of the older Kansan drift of southern Iowa, where once existed broad stretches of poorly drained land, show even more impressively the same characteristics.

The Nebraskan drift, where exposed under the Kansan, commonly shows this same type of profile. Thus we can picture the topographic conditions of broad, flat, poorly drained plains which prevailed during Aftonian time when the Nebraskan drift was weathered to gumbotil, during Yarmouth time when the Kansan drift was similarly weathered, and during Sangamon time when the Illinoian gumbotil was formed.

A profile of weathering on poorly drained Illinoian drift may be seen beneath thin loess, $3\frac{1}{2}$ miles southwest of Effingham, Effingham County, in about the center of Sec. 6, T. 7 N., R. 6 E., at the lower (west) end and on the south side of a youthful, sharply incised gully. (See Plate I, A.) The section is shown on page 40.

A short distance east, perhaps 100 yards up the valley, the original material beneath the thin loess was sand and gravel; now it is completely changed to pebbly *gumbosand* with a transition below into gravelly sand and then dark till. This particular section illustrates admirably how sand and gravel under conditions of poor drainage may be changed into gumbosand, a product markedly different from the original material.

2. *Undulatory, well drained areas.*—Just as poor subsurface drainage conditions beneath broad, flat uplands are reflected in the development of gumbotil, so good subsurface drainage beneath undulatory areas leaves its characteristic profile of weathering. Profiles developed on gently sloping morainic swells or knolls (Fig. 3) on the Illinoian drift, although differing considerably, show characteristically the following: (a) a thinner horizon 1 than that developed in a poorly drained area; (b) no gumbotil in horizon 2, but rather a friable open-textured silt, brownish to buff in color and containing a few small, resistant, siliceous pebbles, for which the name *silttil*¹ seems appropriate, especially in contrast with the name

¹ Attention is here called to the pronunciation of *silttil* which is the same as if it were spelled silt-till; the hyphenated term silt-till, however, is not appropriate as the material is an alteration product from till that may originally have been clayey.



A. Gumbotil profile, $3\frac{1}{2}$ miles southwest of Effingham, Effingham County, Ill. (Reprinted from Chamberlin and Salisbury's "College Geology," 1929.)

Horizon numbers are given along margin.



B. Silttil profile, near Helm, Marion County, Ill. (Reprinted from Chamberlin and Salisbury's "College Geology," 1929.)

Horizon numbers are given along margin.

gumbotil; and (c) a concentration of iron, which may occur partly as concretions, at the top of a fairly thick horizon 3. The color of horizon 3 as developed in a well-drained area is generally reddish rather than yellowish or brownish as in a poorly drained area.

An excellent exposure of a profile developed under good drainage conditions, showing silttil beneath two thin loesses, occurs $\frac{1}{2}$ mile south of Helm station on the new Illinois Central Railway cut-off,



FIG. 3.—Morainal topography of Illinoian age, $5\frac{1}{2}$ miles southwest of Vandalia, Fayette County (photo by MacClintock).

in southeastern Marion County. (See Plate I, B.) The description is given on page 43.

It is conceivable that the comparatively stagnant water under flat areas permits the colloidal clayey products of chemical decomposition to be retained as such, whereas the more active subsurface drainage, as under knolls and ridges or near margins of valleys, either carries out much of the colloidal material, or the conditions favor the aggregation of the colloidal substances into silt particles, leaving a coarser, more open-textured material than the original till.

3. *Partially drained areas*.—Beneath partially drained areas the product of chemical decomposition is intermediate between the very plastic gumbotil and the friable, open-textured silttil; it contains enough clay and silt to make it semiplastic or semifriable and for it

the name *mesotil* is proposed, with the understanding that it applies to a much weathered *derivative* of till.

HELM EXPOSURE, SHOWING PROFILE DEVELOPED ON WELL-DRAINED ILLINOIAN DRIFT IN SOUTHWESTERN MARION COUNTY, ILLINOIS

	THICKNESS	
	Feet	Inches
Early Peorian loess:		
Soil, silty, gray.....	..	7
Silt, yellowish with reddish cast, friable.....	..	3
Silt, clayey, compact.....	1	..
Late Sangamon loess:		
Silt, clayey, heavy; upper part shows vertical columnar structure, the columns break into lumps which are coated with whitish material on the outside, brownish on the inside; the lower part is mottled brown and gray, compact and mostly massive.....	1	8
Illinoian till:		
Horizon 1. Fossil soil:		
Silt, sandy, humous-stained; contains an occasional pebble, mottled brown and gray.....	..	9
Horizon 2. Silttil:		
A. Silt, compact, sandy, slightly plastic, mottled brown and gray, contains few pebbles.....	2	0
B. Silt, sandy, friable, fairly compact, black iron-stain in lower part, contains few pebbles.....	2	0
Horizon 3. Till, leached and oxidized, otherwise but little altered:		
A. Iron-zone, leached, reddish, transected by veins of beidellite; fracture surfaces show iron-stain, pebbles are more numerous and larger than above.....	2	9
B. Till, brownish buff, leached, reddish and yellowish cast, friable; cellular where limestone pebbles have been leached.....	3	0
Horizon 4. Till, oxidized, containing primary calcium carbonate:		
Till, oxidized, calcareous; mottled gray and light yellowish buff, some transecting veins of beidellite.....	7-10	..
Horizon 5. Unaltered till:		
Till, unoxidized, calcareous, at bottom of cut.....	0-3	..

A medium-drained profile, approaching a well-drained profile, may be seen at the Oconee cut in Shelby County, along State High-

way No. 2, about 2 miles northeast of Oconee. The following description is of the south face of the deep road-cut west of Opossum Creek, 20 feet west of the center of the cut:

OCONEE EXPOSURE, SHOWING PROFILE DEVELOPED ON PARTIALLY
DRAINED ILLINOIAN DRIFT IN SHELBY COUNTY, ILLINOIS

	THICKNESS	
	Feet	Inches
Loess (probably Early Peorian):		
Soil, humus, medium-gray, containing occasional small pebbles and pellets of iron oxide up to $\frac{1}{8}$ inch in diameter.	4
Silt, light gray to buff-gray.	10
Clay, silty, compact, plastic, grayish buff to mottled gray and buff; columnar structure in upper part.	1	8
Silt, yellowish.	1	5
(There is some evidence in this area that the basal portion of the loess mantle is Late Sangamon in age.)		
Illinoian till:		
Horizon 1. Fossil soil:		
Silt, humus-stained, friable, brownish to grayish.	1	0
Horizon 2. Mesotil:		
Silt, sandy, grayish buff, containing some small pebbles, mainly non-plastic but with an occasional semiplastic vertical streak; some black iron oxide stains in base, pebbles siliceous and of resistant types.	3	3
Horizon 3. Till, leached and oxidized, otherwise but little altered:		
A. Till, reddish buff tone, iron-rich beidellite zone in upper part, vertical streaks of dark gray beidellite running through a silty sand matrix, mottled grayish buff and black; pebbles larger and more numerous than above, and an occasional ironstone concretion up to 2 or $2\frac{1}{2}$ inches in diameter; partly decomposed granite and diorite pebbles. This horizon produces a shoulder along the slope of the cut and checks on dry surface owing to cross-veins of beidellite.		
	1	9
B. Till, leached, grayish buff, silicate pebbles mostly firm.		
	2	3
Horizon 4. Till, oxidized, containing primary calcium carbonate:		
Till, oxidized, calcareous; transition zone of leaching at top is limited to about 3 inches below which limestone pebbles are firm and unetched.	10+	..

The variety of topographic forms which control the moisture conditions of the subsoil, and the transitions from one to another, cause the development of soil profiles that represent all gradations between those characteristic of poorly drained and those characteristic of well-drained areas. For example, an exposure 1 mile east of Effingham, Effingham County, along a road-cut through the upper part of the east valley wall of Salt Creek, shows an intermediate profile more closely related to the poorly drained profile than is the Oconee exposure just described. Horizon 2 of the profile of weathering on the drift, beneath the overlying modified loess, contains more clay than horizon 2 of the Oconee exposure, and yet is not a true gumbotil.

Obviously, the majority of profiles seen in an undulatory area are intermediate between the two extreme types, namely, the gumbotil and siltil profiles, and might be classed as medium-drained or *mesotil* profiles. They show commonly a light silty horizon 1 and a more or less heavy horizon 2, depending on whether the particular profile studied was produced under conditions approaching poor drainage or good drainage (Fig. 4).

The thesis of the present article embodies the modern concept that the weathered zone is a dynamic whole which is continually subject to changes under environmental influences and for that reason shows alteration, gradation, and evolution from time to time as well as from place to place.

VEGETATION

1. Synchronous with the other factors of soil genesis, vegetation plays a rôle. Luxuriant grasses on prairies commonly give rise to a horizon 1 highly charged with black humus material, whereas a forest cover in the same climatic zone on flat tracts results in light gray material below a thin blanket of forest litter, becoming yellowish gray on undulatory tracts.

2. Vegetation on a gentle slope, in a moist climate, may become so luxuriant as to cause medium or poor drainage, where without the heavy plant cover a well-drained profile might develop.

3. Likewise, poor subsurface drainage conditions on a gentle

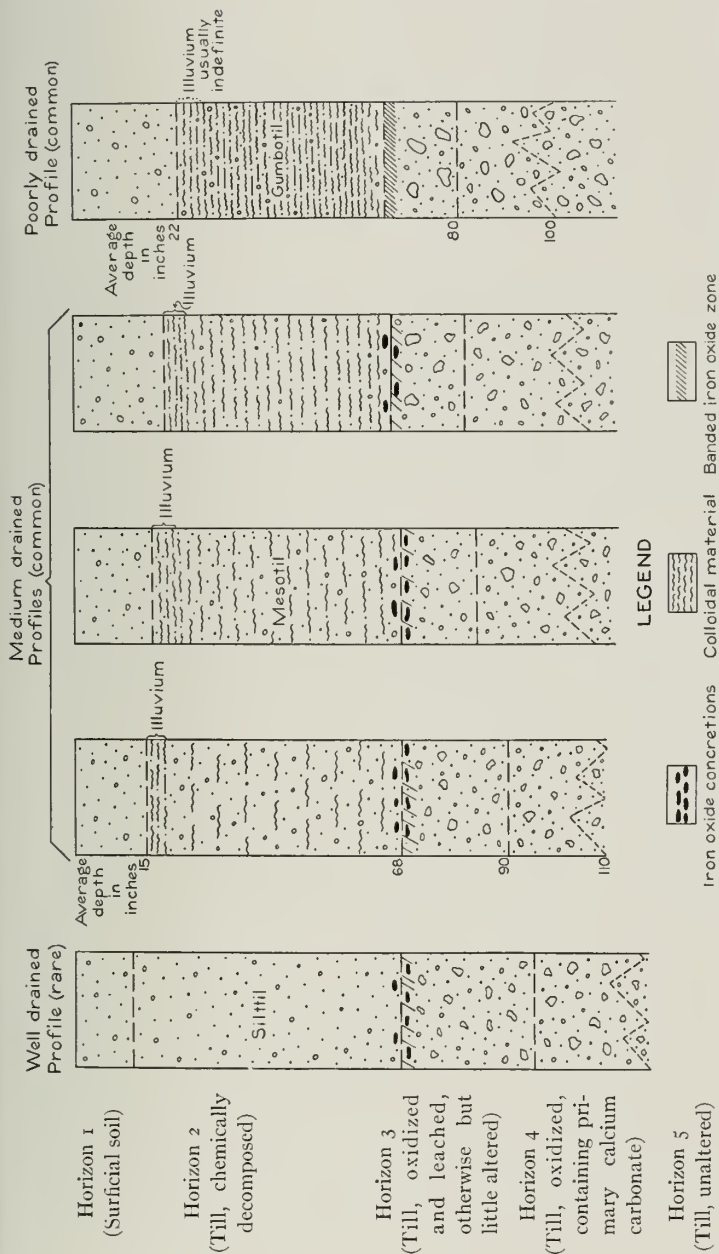


FIG. 4.—Diagrammatic summary of the gradational series of weathered profiles on the Illinoian drift in southern Illinois, from the well-drained to the poorly drained types (thicknesses given are averages from computations made by courtesy of R. S. Smith and E. A. Norton, Illinois State Soil Survey).

slope may prevail while there is sufficient lime near the surface to support a luxuriant vegetation, but when the lime becomes deeply leached and the soil therefore becomes infertile the vegetation becomes light and the subsurface drainage better. There will be a consequent change in the weathered profile, the character of which will depend upon the length of time that has elapsed since the change took place.

PERMEABILITY OF THE PARENT OR SUBJACENT MATERIAL

1. Where the parent-material was originally somewhat impervious to ground water, weathering has proceeded more slowly and the profile developed is not so deep and may not be so well drained as the type found in similar topographic positions on the same drift where all the material is easily penetrated by percolating waters. Good examples are seen on the Paxton and Marseilles moraines where profiles developed in morainal belts of heavy clayey material approach the type characteristic of poor drainage conditions.

2. Impervious subjacent material affects the profiles formed in thin superjacent material. Thus the profile developed in relatively thin loess lying on gumbotil, other conditions being the same, shows a poorer drainage during its development than where the loess is underlain by porous material.

COMPARATIVE DEVELOPMENT OF WEATHERED ZONES ON THE VARIOUS DRIFT-SHEETS OF THE MIDDLE WEST STATES

The length of time that a drift-sheet has been subjected to weathering is an important factor in the stage of development of its weathered profiles.

The Wisconsin drift shows a shallow, youthful, less obviously differentiated profile of weathering than that of the Illinoian drift. That portion of the Wisconsin profile which corresponds to horizons 1, 2, and 3 of the Illinoian and older drift-sheets is only from $2\frac{1}{2}$ to 4 feet thick, as compared with a much greater thickness for the older drifts. Indeed, horizon 2 of the Wisconsin drift in many places is not yet sufficiently deep to be easily differentiated from horizon 1.

In the Iowan drift area, the topography is mainly undulatory and for the most part has well drained or partly drained profiles of weathering. In some localities poor drainage conditions prevail on

the uplands, but in any case the weathered zones show a youthful stage of development but slightly more advanced than that of the weathered zone of the Wisconsin drift.

The Kansan weathered zone shows the same divisions of the weathered profile as does the Illinoian, but thicker and in a still more advanced stage of development. Most of the described weathered zones on the Kansan drift exhibit gumbotil profiles. The gumbotil (horizon 2) is more plastic and the pebbles are fewer and smaller than in horizon 2 of the Illinoian drift. With the conception of weathering profiles in mind, further study of the Kansan drift area may reveal belts of former morainal topography, now greatly subdued and eroded, but possessing the silttil profile, that is, reflecting original good drainage conditions.

The buried gumbotil profile of the Nebraskan drift approaches that of the Kansan in its stage of development.

AREAL AND CORRELATIVE IMPORTANCE OF THE POORLY DRAINED,
THE MEDIUM-DRAINED, AND THE WELL-DRAINED
WEATHERED PROFILES

In central, south-central, and western Illinois, southern, eastern, and western Iowa, and northern Missouri, there are broad, flat, tabular divides where the poorly drained profile prevails. Indeed, it was in southern Iowa that the occurrence of gumbotil was first recognized by McGee¹ and later worked out and its importance emphasized by Kay.²

On the other hand there are large rolling areas, as in southern Illinois, where the original thickness of the drift was not sufficient to fill the bedrock valleys, and where belts of morainal topography occur, in which the medium-drained profile prevails, with an occasional local occurrence of the well-drained profile. In northwestern Illinois the same situation holds; also in the Iowan drift area of northeastern Iowa, the older drift area of the northeast corner of Iowa, and the thin drift area of northeastern Kansas. Doubtless there are similar conditions of alternating flat and undulatory areas

¹ W. J. McGee, "The Pleistocene History of Northeastern Iowa," *U.S. Geol. Survey, 11th Ann. Report, Part I* (1891), p. 509.

² G. F. Kay, and J. N. Pearce, "The Origin of Gumbotil," *Jour. Geol.*, Vol. XXVIII, No. 2 (1920), pp. 89-125.

in Wisconsin, Minnesota, North Dakota, Montana, South Dakota, and Nebraska. In the western part of the Mississippi basin, however, the smaller amount of rainfall is probably reflected in the development of profiles of weathering quite different from those discussed in the present article. But within the region whose climate is closely similar to that of Illinois, it is important for the glacial geologist and the pedologist to bear in mind the characteristic environmental responses of the weathering processes and the consequent profiles of weathering herein described.

In the middle states, and particularly in Illinois, it has been found that the average thickness of horizon 2 of the silttil and mesotil profiles is slightly greater than that of the gumbotil profile. Apparently the somewhat greater run-off in the one case is more than balanced by the slow percolation of water in the other. At any rate, the important fact is that in areas of the same climate, horizon 2 of the mesotil profiles, where erosion is not excessive, has essentially the same value in correlating or differentiating drift-sheets as horizon 2 of the gumbotil profile.

SECOND-CYCLE PROFILES

After a long period of weathering under poor drainage conditions, resulting in the development of a gumbotil profile, erosion may work headward into the area and bring about a change to better drainage conditions, both surface and subsurface. In such an event the profile is changed, first in horizon 1 and then in horizon 2. The colloidal material in horizon 2 is either removed and carried away by ground water or is precipitated to form silt particles. Beginning at the top and working downward, the change becomes more marked and deeper out near the slope where the new conditions are first felt, and is less evident back under the upland (Figs. 5*a* and 5*b*). If the change is not complete (and in many cases it is not), there will be a second-cycle mesotil or silttil profile transecting the old horizon 2; the buff-colored open-textured silttil of the new, resembling pebbly loesslike silt, resting upon a remnant of gumbotil, and with an iron pellet zone separating the two.

In Figures 5*a* and 5*b*, is recorded the following history: first, there developed the glacial climate of the Illinoian stage which re-

sulted eventually in ice invasion and deposition of the till; second, the climate moderated, the ice receded, and weathering proceeded



FIG. 5a.—Exposure showing a two-cycle weathered profile on glacial drift beneath loess, resulting from dissection after development of the gumbotil and before deposition of the loess. One mile east of Trenton, Illinois, east-central part of Sec. 21, T. 2 N., R. 5 W., Clinton County (photo by MacClintock).

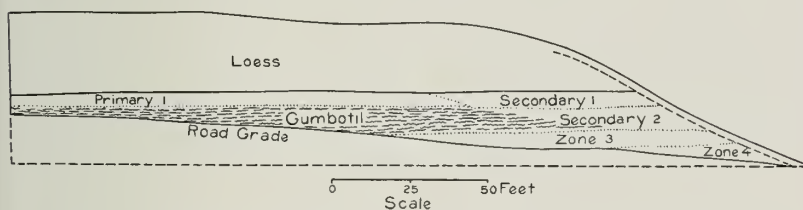


FIG. 5b.—Diagrammatic sketch of exposure (Fig. 5a), showing the character of the material, the relations of the secondary profile to the primary, and the relations of both to the loess.

under poor drainage conditions for a long period of time, producing the gumbotil profile; third, erosion finally worked headward, chang-

ing the conditions of weathering from those of poor drainage to those of good drainage, and adjacent to the valley a secondary profile was developed upon the primary profile; fourth, the development of the secondary profile was brought to a close by an episode

BIG CREEK EXPOSURE OF INTERGLACIAL SOIL, S. CEN. NW $\frac{1}{4}$ SEC. 2,
T. 11 N., R. 12 W., CLARK COUNTY, ILLINOIS

	THICKNESS	
	Feet	Inches
Illinoian till:		
Till, leached	7	..
Till, calcareous, oxidized, dark buff-colored	18	..
Till, calcareous, dense, blue-gray, containing wood and gas-tropod shells in lower part	25	..
Pre-Illinoian till:		
Secondary profile:		
Horizon 1:		
Moss or grass	$\frac{1}{2}$
Soil, calcareous, fossiliferous	2
Silt, light, powdery, fluffy, reddish brown; horizontal fracture tendency; leached	1	..
Horizon 2:		
Mesotil, dense, compact, leached, conchoidal fracture with columnar tendency; contains few scattered siliceous pebbles	3	6
Primary profile:		
Horizon 2:		
Gumbotil, bluish gray to brownish	2	..
Horizon 3:		
Subgumbotil, iron-stained and in places iron-cemented; leached	1	6
Horizon 4:		
Till, calcareous, drab-brown, dense, hard	4	..
Horizon 5:		
Till, calcareous, blue-gray, dense	18	..
(Covered by slump)	10	..

of loess deposition. The negligible quantity of loess on the valley slopes in this case is clearly due either to removal almost as rapidly as it was deposited or to its subsequent removal.

In some places an earlier till, having both a primary and a secondary profile, is overlain by another drift rather than by loess, as,

for example, the Nebraskan drift overlain by the Kansan drift. Where the glacialist is so fortunate as to find the top soil of the buried drift preserved, he has before him a complete interglacial record, illuminated by the recognition of the two profiles of weathering. The Big Creek section¹ in Clark County, is illustrative.

The recognition of the mesotil or the silttil profile, whether of a first or second cycle, is important in drawing the boundary between

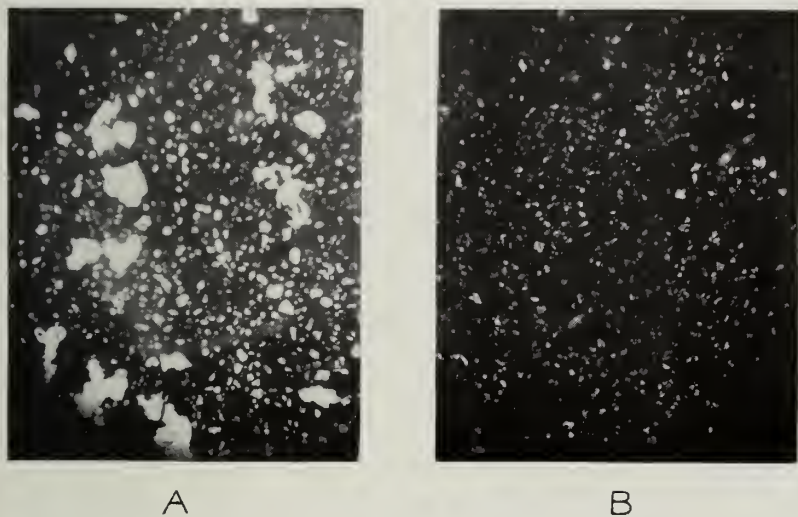


FIG. 6.—Photomicrograph of (A) silttil and (B) loess. Crossed nicols, magnified 30 times (photo by Leggette).

loess and till. In times past it has been common to consider any loesslike silt containing a few scattered pebbles as the basal part of loess, on the assumption that the pebbles were introduced by secondary agencies from the till below during the opening phase of the loess deposition. This is of course possible, and it is pertinent, therefore, to look for differentiating criteria. Under the microscope true loess looks remarkably uniform in size and shape of particles, whereas silttil is exceedingly irregular and heterogeneous. The contrast is well shown in Figure 6.

If the exposure is situated at the brow of a slope or just back

¹ Paul MacClintock, "Recent Discoveries of Pre-Illinoian Drift in Southern Illinois," *Illinois State Geol. Survey, Report Inv. No. 19* (1929).

from it, it is likely to contain a trace of an old surficial soil at the very top of the loesslike silt which carries the scattered pebbles. The loesslike silt in such a case is the *silttil* of a well-drained profile of weathering.

On a steep slope, however, where a pebble line separates till from pebbly loesslike material, the loesslike material is due to slope-wash, either from the partly drained profile higher up on the slope or from the first loessial covering.

SUMMARY

The study of weathered zones has revealed that there is a response to the physiographic and vegetative environment, as well as to the climatic and subsurface drainage conditions; that the ultimate product of weathering, as represented in horizons 1 and 2, is radically different in chemical composition, structure, texture, and consistency from the parent-material; that the *gumbotil* of the poorly drained profile has its counterpart in the *mesotil* of the medium-drained profile and in the *silttil* of the well-drained profile; that the weathered zone passes through orderly stages of development; and that with a change from physiographic conditions of poor drainage to those of partial or good drainage, there is instituted a second cycle of profile development, that is, eluviation of the poorly drained gumbotil profile to make the medium-drained mesotil profile or the well-drained silttil profile. It therefore seems possible to interpret with considerable confidence the physiographic history of interglacial times.

This conception of weathered zones relates them to their physiographic, climatic, and vegetational setting; provides the framework for a comprehensive study of weathered zones and their profiles; provides criteria for drawing more precise boundaries between weathered till and superjacent loess; illuminates interglacial history; stresses the importance of environmental factors as well as climatic factors in the classification of soils; promises a new line of attack for the study of the evolution of plants; and stimulates another angle of approach to the study of the underclays of coals and of unconformities between certain types of materials in our bedrock and unconsolidated formations.

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