GUMBOTIL, ACCRETION-GLEY, AND THE WEATHERING PROFILE

John C. Frye
H. B. Willman
H. D. Glass

DIVISION OF THE
ILLINOIS STATE GEOLOGICAL SURVEY
JOHN C. FRYE, Chief   URBANA

CIRCULAR 295   1960

GUMBOTIL, ACCRETION-GLEY, AND
THE WEATHERING PROFILE

John C. Frye, H. B. Willman, and H. D. Glass

ABSTRACT

Mineralogical studies have been made of the weather-
ing profiles of the glacial till plains of Illinois. A comparison
is made between profiles developed in situ and those that in-
clude accretion-gley.

In the upper part of the in situ profiles there is a sig-
nificant depletion of the Na-Ca feldspars and garnet and ap-
preciable depletion of ferromagnesian minerals. K-feldspar,
tourmaline, zircon, and epidote show no measurable effect of
weathering. Of the clay minerals in the till, the chlorite and
biotite-type micas alter successively to vermiculite-chlorite,
vermiculite, mixed-lattice clay minerals, and expandable ver-
miculite. Muscovite is more resistant.

Compared with the in situ profiles, the accretion-gleys
show less mineral decomposition and possess a mixture of
clay minerals ranging from chlorite to montmorillonite that in-
dicates physical mixing rather than alteration in place. The
total weathering effect in all materials studied is strikingly
less than that attributed to gumbotil.

It is concluded that the term "gumbotil" has not been
sufficiently restricted to render it a useful scientific term.
Deposits of accretion-gley can be differentiated from in situ
weathering profiles in the field, and such profiles should be
described in terms of defined zones.

INTRODUCTION

The surface of the extensive plain of Illinoian glacial till in Illinois is
characterized by a strongly developed profile of weathering. This profile gener-
ally is covered by loess, till, or outwash. It has a relatively wide range of ex-
pression, similar to that of the profiles that occur on the surfaces of the older
till sheets of the Midwest.

One distinctive expression of the weathering profile is characterized by
gray clay and has been named "gumbotil" (Kay, 1916a; Kay and Pearce, 1920).
As has recently been pointed out (Frye, Shaffer, Willman, and Ekblaw, 1960),
materials that meet the gross physical requirements of gumbotil may have originated
in several ways, but probably the most common origin was the slow accretion of
fine-textured materials to form a deposit in shallow undrained areas on the initial
till plain surface. Deposits of this type, which commonly have been classed as
gumbotil, were named "accretion-gley" and the term "gumbotil" was restricted to

the products of in situ weathering formed where drainage was sufficiently poor to produce gleying.

The field relations of accretion-gley deposits have been described (Frye, Shaffer, Willman, and Ekblaw, 1960). It is our purpose here, from mineralogic studies of the sand and finer fractions of accretion-gleys and of in situ weathering profiles developed in the same glacial tills, to determine criteria distinguishing the two types of material and to develop evidence bearing on the origin of the materials.

The samples used for laboratory analysis in this study are listed in table 1, which gives also their sand content and solubility in hydrochloric acid. Percentages of feldspars and heavy minerals are given in table 2, and results of X-ray analyses in table 3. Many of these data are shown diagrammatically in figures 1, 2, 3, 4, and 5.

To discuss the positions of samples within the profile of weathering it is necessary to define the subdivisions that are used. In this report standard pedologic nomenclature (U.S. Department of Agriculture, 1951) is used insofar as practical. Because our study is concerned with the deeper parts of the profile as well as with the shallow portions, it has been necessary to expand the terminology for this deeper part. In pedologic literature the G-horizon is applied to gleyed material of both in situ development and slow accumulation. To clarify its use in this report, G-zone is applied only to accretion-gley. The following definitions apply to the zones of the profiles as used in this report. Where standard pedologic nomenclature is mentioned, reference is made to the Soil Survey Manual (U.S. Department of Agriculture, 1951).

Weathering Profile Terminology

A-zone   =   The A-horizon, with subdivisions of A_1, A_2, and A_3, of standard pedologic terminology.

B-zone   =   B-horizon, with subdivisions of B_1, B_2, and B_3, of standard pedologic terminology. Commonly oxidized to some shade of red or brown; contains soil structure, clayskins, and commonly Mn-Fe pellets. It is the zone of clay enrichment.

BG-zone =   A zone that may occur in the position of the B-zone in a profile developed in situ. It may represent a modification of a part of the B-zone. It has clay accumulation but displays only a limited range of soil structures. The reducing environment produces some shade of gray in color. A BG-zone commonly is a secondary modification of a primarily developed B-zone and therefore may display Mn-Fe pellets and some other characteristics of the B-zone.

C-zone   =   Weathered parent material that generally occurs next below the B-zone, but may be below an A-, BG-, or G-zone. In those areas where the parent material was initially calcareous, the C-zone is divided into a CL-zone and a CC-zone.

CL-zone =   Leached C-zone. The zone below the B that is leached of primary carbonates; it may be strongly to weakly oxidized, but does not display soil structure.

CC-zone =   Calcareous C-zone. The zone below the CL-zone (where present) that contains primary carbonates. It is oxidized and displays the

structure of the parent material. In many sections a subzone occurs at the top from which calcite has been leached but which retains dolomite.

G-zone   =   Accretion-gley. An accumulation of fine-textured material characterized by an abundance of clay, derived by slow lateral transport from adjacent gentle slopes (with or without increments of loess) and deposited in an undrained position in the microtopography where semi-permanent water produces a reducing environment. Some organic material may be present, soil structure is generally absent, and in some places indistinct bedding may be observed. The color is always some shade of gray.

Acknowledgments

We wish to thank George E. Ekblaw, Illinois State Geological Survey, and Paul R. Shaffer, University of Illinois, who have read and criticized this manuscript. Preparation of samples and grain counts of heavy minerals and feldspars were done by James Bloom, John Humes, Constantine Manos, and Richard Mast. Determinations of sodium and potassium of ten samples were made by L. D. McVicker, and W. F. Bradley assisted in interpretation of the X-ray data.

THE GUMBOTIL CONCEPT

Concentrations of clay on the surfaces of till plains have been recognized since the past century. The terms "gumbo" and "gumbosoil" were in common use for these conspicuously plastic materials. Kay (1916a; 1916b) pointed out that this type of gumbo material occurred on the surfaces of Nebraskan, Kansan, and Illinoian tills, both where these tills were covered only by loess and where they were overlain by younger drifts. He proposed (Kay, 1916a) the term "gumbotil" for this material, and ascribed to it a concept of origin that he considered applicable to all such deposits on all till plains. He defined gumbotil as follows:

Gumbotil is, therefore, a gray to dark colored, thoroughly leached, nonlaminated, deoxidized clay, very sticky, and breaking with a starchlike fracture when wet, very hard and tenacious when dry, and which is chiefly the result of weathering of till. The name is intended to suggest the nature of the material and its origin, and it is thought best to use a simple rather than a compound word. Field work has already established the fact that in Iowa there are three gumbotils, the Nebraskan gumbotil, the Kansan gumbotil, and the Illinoian gumbotil.

In 1920, Kay and Pearce discussed at length the origin of gumbotil and reaffirmed the 1916 definition and interpretation. They presented data demonstrating that the percentage of siliceous pebbles was higher and the size of the pebbles much smaller in the gumbotil than in the underlying leached and unleached tills. They also described the presence of recognizable boulders in various stages of disintegration in the leached till below the gumbotil (but not in the gumbotil itself), and presented the results of 11 chemical analyses of calcareous till, leached till, and gumbotil. They pointed out a downward increase in the proportion of soluble diffusible constituents and a downward decrease in the proportion of alumina. Expressing their genetic interpretations, they stated (Kay and Pearce, 1920, p. 122):

The stratum now forming, deprived of practically all of its sodium and potassium, of most of its calcium and magnesium, and some of its iron and silica, is the present residuum of the whole chemical leaching process. This is the gumbotil.

In 1929, Kay and Apfel reviewed the earlier work on gumbotil and presented data supporting the previous conclusions. Their confirmation of the earlier work is emphasized by the statement (Kay and Apfel, 1929, p. 112):

The resultant residuum of the chemical leaching process is a practically insoluble stratum — the gumbotil. In addition, such physical factors as wind action, freezing and thawing, and burrowing of ground animals may have played some part.

In 1930, Leighton and MacClintock reported the results of studies of weathering profiles on tills in Illinois. They supported the conclusions of Kay and his co-workers concerning the origin of gumbotil. They proposed a five-fold zonation of the weathering profile on till surfaces, which they called horizons I to V in descending order. They described (1930, p. 31) Horizon II as:

Chemically decomposed till, composed chiefly of alteration products and resistant constituents of the original till, and strikingly unlike the original till.

To this horizon they assigned gumbotil as the product of a poorly drained topography and introduced the terms "siltil" and "mesotil." Siltil was defined as the weathering product of a well drained area and mesotil as the weathering product of an intermediately drained area.

Their views concerning the development of the several horizons are clearly stated (1930, p. 35) as follows:

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.

Their views concerning the relation of gumbotil to Horizon II are further amplified (1930, p. 37) by the statement:

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.

Subsequent to the 1930 publication by Leighton and MacClintock, relatively little new data have been presented concerning gumbotil. Pedologists generally

did not oppose the concept, although a few presented some objections to it (Kruse-kopf, 1948; Simonson, 1954). On the other hand, writers of geology textbooks have completely accepted the early concepts of origin and have treated them as established facts by referring to the B-horizons and the gumbotil as zones of nearly complete decomposition of silicate minerals.

In recent years a few papers (Gravenor, 1954; Ruhe, 1956; Brophy, 1959; Allen, 1959) have presented additional mineralogical data on weathering profiles (including gumbotils) in till. Critical examination indicates some of these data are incompatible with the previously developed concept of complete chemical weathering of silicates in gumbotil. Ruhe (1956, p. 449) noted the occurrence of slopewash or accretion deposits in the upper part of humic-gley profiles on till in Iowa.

In 1960, in a review of the field relations of gumbotil, Frye, Shaffer, Willman, and Ekblaw concluded that material meeting the requirements of the empirical definition of gumbotil has been formed in several strikingly different ways. Even here, however, because of lack of significant mineralogical data, the notion of extreme decomposition of silicate minerals in in situ weathering profiles was not challenged.

SUMMARY OF INTERPRETATIONS

A critical examination of the mineralogical data shows that the concept of gumbotil origin is fallacious in several respects:

1) In neither the B-zones of in situ profiles nor in the accretion-gley layers do the silicate minerals approach the stage of complete decomposition. Only a moderate decrease in the abundance of feldspars and other silicate minerals occurs.

2) At most, only a moderate decrease in sodium and potassium occurs in the B-zones and the accretion-gleys.

3) The small size and scarcity of pebbles in many materials called gumbotil (accretion-gley) is the result of mechanical sorting of a material from which the carbonate rocks have been removed.

4) The addition of clay to the B-zone can be accounted for only by down-ward movement of clay. The feldspars and other minerals that might have yielded additional clay are largely still present in the B-zone and although the clay minerals originally present are altered this change does not add to the total clay. The increase in clay content occurs entirely in the less than 0.5-micron size, another fact that favors downward movement of the additional clay.

5) In the in situ profiles there is a progressive alteration of the clay minerals, whereas the accretion-gley contains an assemblage of clay minerals of strikingly different degrees of weathering, suggesting a mechanical mixture.

6) The data suggest that in general the degree of chemical weathering, as measured by depletion of feldspars and ferromagnesian minerals, is greater in well drained than in the poorly drained areas.

The mineralogical data confirm the earlier conclusion (Frye, Shaffer, Willman, and Ekblaw, 1960) that the weathering profiles developed on the surfaces of the till plains of Illinois are of two major types: 1) in situ weathering profiles, and 2) accretion-gley deposits. The term "gumbotil," although in some places applied to the partially gleyed BG-zones of in situ profiles, has been widely used for the accretion-gley deposits.

The most important mineralogical changes that occur when tills weather in place result from: 1) removal of the carbonate minerals progressively downward; 2) alteration of some of the existing clay minerals; and 3) the downward illuvial movement of some fine clay into the B-zone.
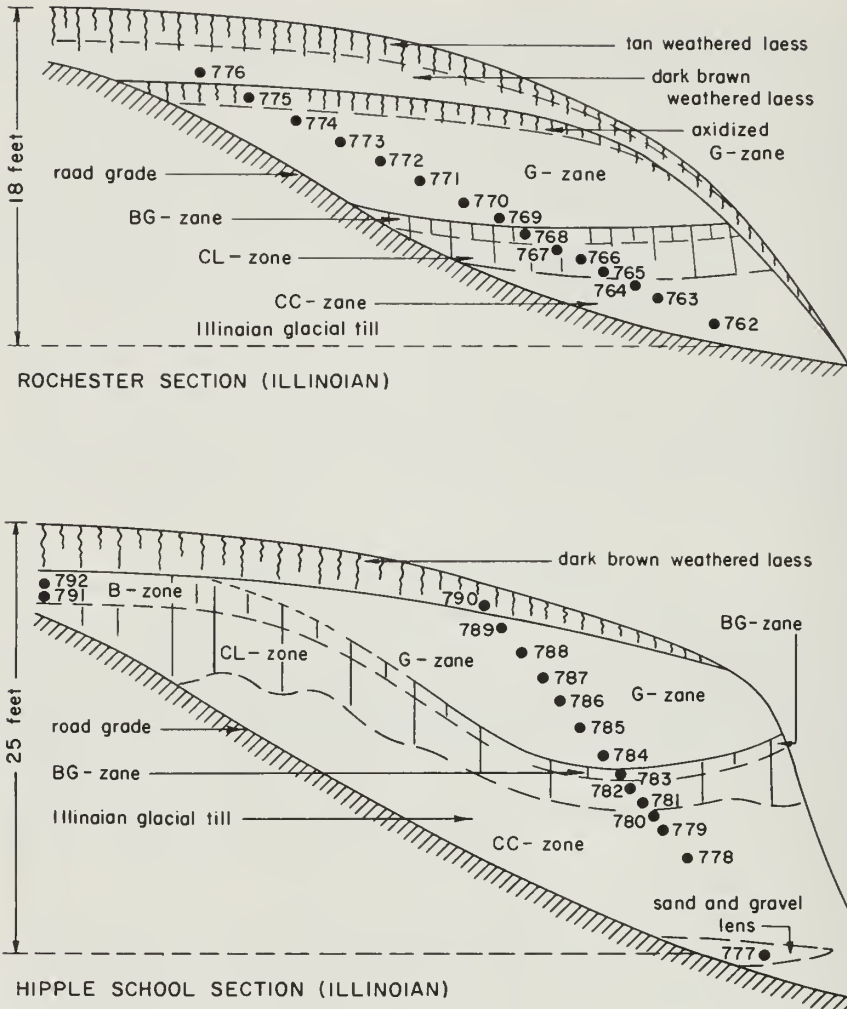
Fig. 1 – Generalized field sketch of relation of Rochester and Hipple School samples to zones in weathering profiles that contain accretion-gley.

Accretion-gley deposits that commonly have been classed as gumbotil are the product of slow accumulation of predominantly fine-textured material in poorly drained or undrained areas on the constructional surface of the till plain left after retreat of the glacier. In some places minor increments of aeolion silt may have been incorporated into the accretion-gleys. However, the striking similarity of the mineralogy of the silt and sand sizes from the accretion-gleys to that of the A- and B-zones of in situ profiles of weathering indicates that the predominant source of accretion-gley is in the adjacent gentle slopes of weathered till.

The relatively large percentage of montmorillonite in accretion-gleys has been considered evidence that a large part of the deposit is derived from loess. However, the similarity of the mineralogy of the silt- and sand-size fractions

of the accretion-gleys to that of the till profiles, the common presence in the ac-
cretion-gley of small, scattered pebbles that are derivable from adjacent slopes
(but not from loess), and the stratigraphic position and geographic location of the
deposits with respect to known identifiable loess deposits argue against such a
hypothesis. When these data are added to the field data, including the occurrence
of lenses of accretion-gley in a down-slope relation to slopes (fig. 1) locally dis-
playing pebble concentrates, the postulated origin of the accretion-gley as a pre-
dominantly sheet-wash deposit, derived largely from adjacent slightly higher areas
of the till plain, becomes inescapable.

DISCUSSION OF DATA

The Illinois State Geological Survey is engaged in a broad investigation of
the mineralogy and petrology of the Pleistocene deposits of the state, of which the
present report is one part. Data are reported from 193 samples from 61 localities in
Illinois; 124 of these samples are from Illinoian age till and the remainder from
tills of Kansan and Wisconsinan age, the latter including both Altonian (Winnebago)
and Woodfordian tills (Frye and Willman, 1960). Included in the samples are 42 for
which analyses were published previously (Brophy, 1959; Willman, 1942) and for
these only the supplemental data are presented here.

Many of the variations in the feldspar and heavy mineral percentages in the
weathering profiles result from variations in the till before it was weathered. In
some localities these original variations appear to be as great as the extremes pro-
duced by weathering. As a result, generalizations are based on averages of many
samples (table 4) and specific examples are presented from selected localities in
which progressive mineralogical changes indicate a relatively uniform mineral dis-
tribution in the original material.

Mineralogical data are pertinent to an evaluation of weathering effects
when examined in terms of vertical variations throughout the profile. Such an
evaluation may be made by use of the composition of the unaltered till below the
profile as a standard of reference. Further comparisons may be made between dif-
ferent points in the profile by use of other standards of reference. To make such
comparisons the following equations were used:

$$\frac{X1}{X2} \times \frac{Y2}{Y1} = Z$$

$$100 - Z = \text{percentage of depletion}$$

where:

X1 = percentage of reference mineral in reference zone.
X2 = percentage of reference mineral in zone being analyzed.
Y1 = mineral being tested for depletion, percentage in reference zone.
Y2 = mineral being tested for depletion, percentage in zone being analyzed.

For example, using the data from table 4 and calculating the depletion of
Na-Ca feldspar in the A-zone, using K-feldspar as the reference mineral, and the
CC-zone as the reference zone, the depletion is as follows:

$$\frac{12}{11} \times \frac{5}{8} = 0.68 = 68 \text{ percent remaining}$$

$$100 - 68 = 32 \text{ percent depletion}$$

Carbonate Minerals

The content of carbonate minerals and rocks in the unaltered Illinoian till is generally between 20 to 30 percent; in unaltered Wisconsinan tills it is somewhat higher. The carbonate minerals, generally more dolomite than calcite, have peaks of abundance in the pebble and silt sizes. They have minima at the peaks of abundance of other minerals, particularly where the carbonates are diluted by clay in the clay fraction, by quartz in the sand sizes, and by igneous and metamorphic rocks among the boulders (table 3). The greatest volumetric effect of weathering of glacial till has resulted from the solution of the carbonate minerals. The only processes that are observable at somewhat greater depths below the surface of weathering are oxidation and beginning alteration of some clay minerals.

In the upper few feet of the CC-zone there is commonly 10 to 15 percent less soluble material than in the lower part of the zone, and X-ray determinations indicate that almost all the carbonate present in the subzone is dolomite. No conspicuous line of demarcation distinguishes the base of this subzone, and, despite the considerable reduction in volume, no significant structural change is involved. In the field, the presence of the subzone is detectable by its slow reaction to acid.

The presence of a subzone of partial leaching is predictable because of the great differences in solubility of the carbonates. Laboratory experiments show that in a given sand size, the calcite of a prepared mixture of calcite and dolomite can be completely dissolved by hydrochloric acid without significant loss of dolomite. The subzone has been considered to be very thin in soil profiles on tills. Several samples collected to represent the calcareous till fall within this subzone rather than in the entirely unleached material (table 3).

Feldspars

The feldspars generally are recognized as minerals that are subject to chemical decomposition as the result of weathering processes. Goldich (1938) showed that in the pre-Cretaceous weathering of a granite gneiss in Minnesota the Na-Ca feldspars are highly susceptible to weathering and are largely depleted before the K-feldspars are affected, but that as weathering proceeds the K-feldspars also are removed, leaving a predominance of kaolinite and quartz. The feldspar content of the silt and sand fractions should, therefore, serve as an index to the degree of weathering in the till profiles. Another advantage in using feldspars as indices is that their original abundance decreases only moderately with increasing size. For example (table 2), the abundance of the K-feldspar from the very fine sand fraction averages 13 percent, from the fine sand fraction 11 percent, and from the medium sand fraction 8 percent.

In the fine and very fine sand fractions in unaltered Illinoian till (fig. 2; table 4), there is an average of 11 percent K-feldspar and 10 percent Na-Ca feldspars or a total of 21 percent feldspar. Proceeding upward in a weathered profile, the CC-zone averages 20 percent, the CL-zone 21 percent, the B-zone 18 percent, and the A-zone 16 percent feldspar. The change is progressive throughout the · profile without regard to the boundaries of the zones. In five sections where closely spaced samples were available,the uppermost sample in the CL-zone averaged 20 percent feldspar and the lowest sample from the B-zone averaged 21 percent feldspar. Relative to quartz this represents a depletion of 12 percent of feldspar in the B-zone and of 24 percent in the A-zone. The average feldspar content for the accretion-gleys resting on Illinoian till is 18 percent, the same as for the B-zones of the in situ profiles.
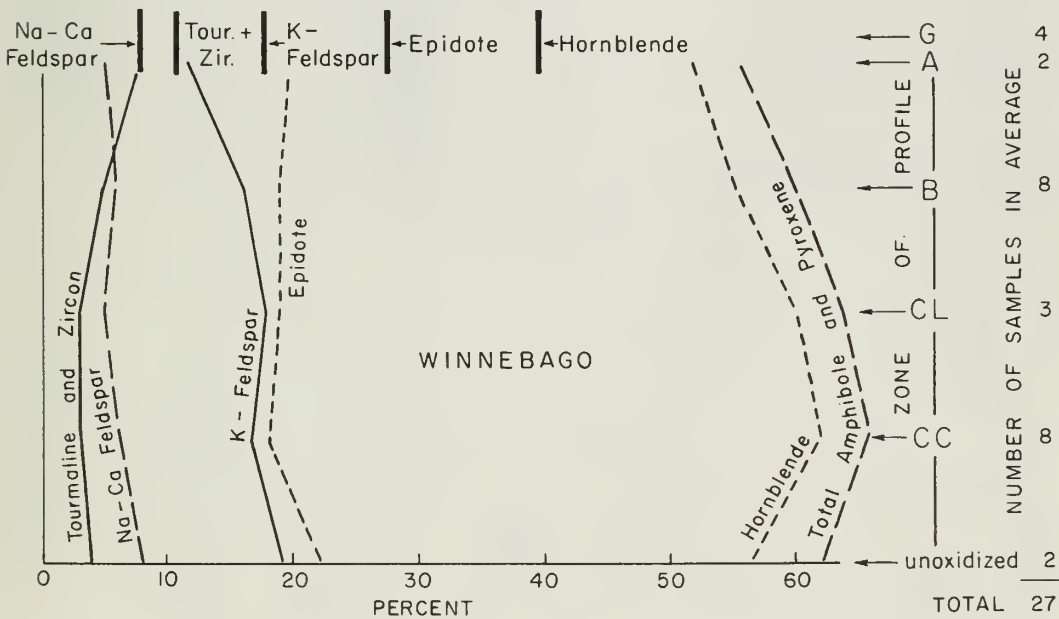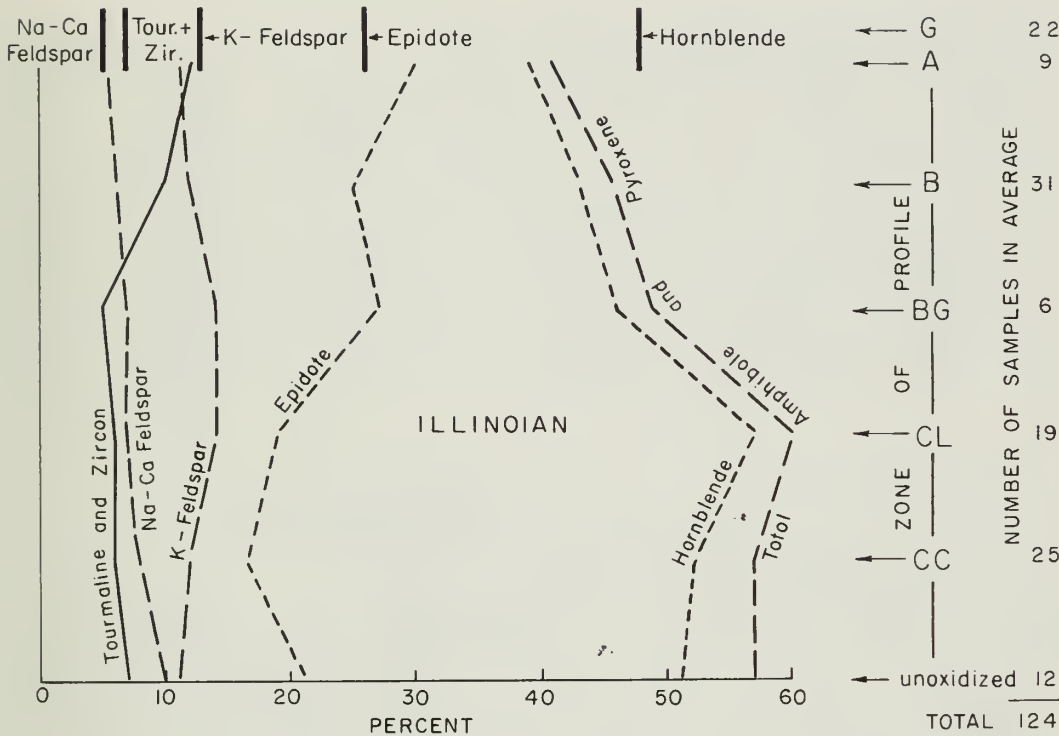
Fig. 2 – Average values for mineral constituents of the several zones of in situ
profiles developed on Illinoian and Winnebago tills. The average composition
of accretion-gleys is shown by bars at the top.
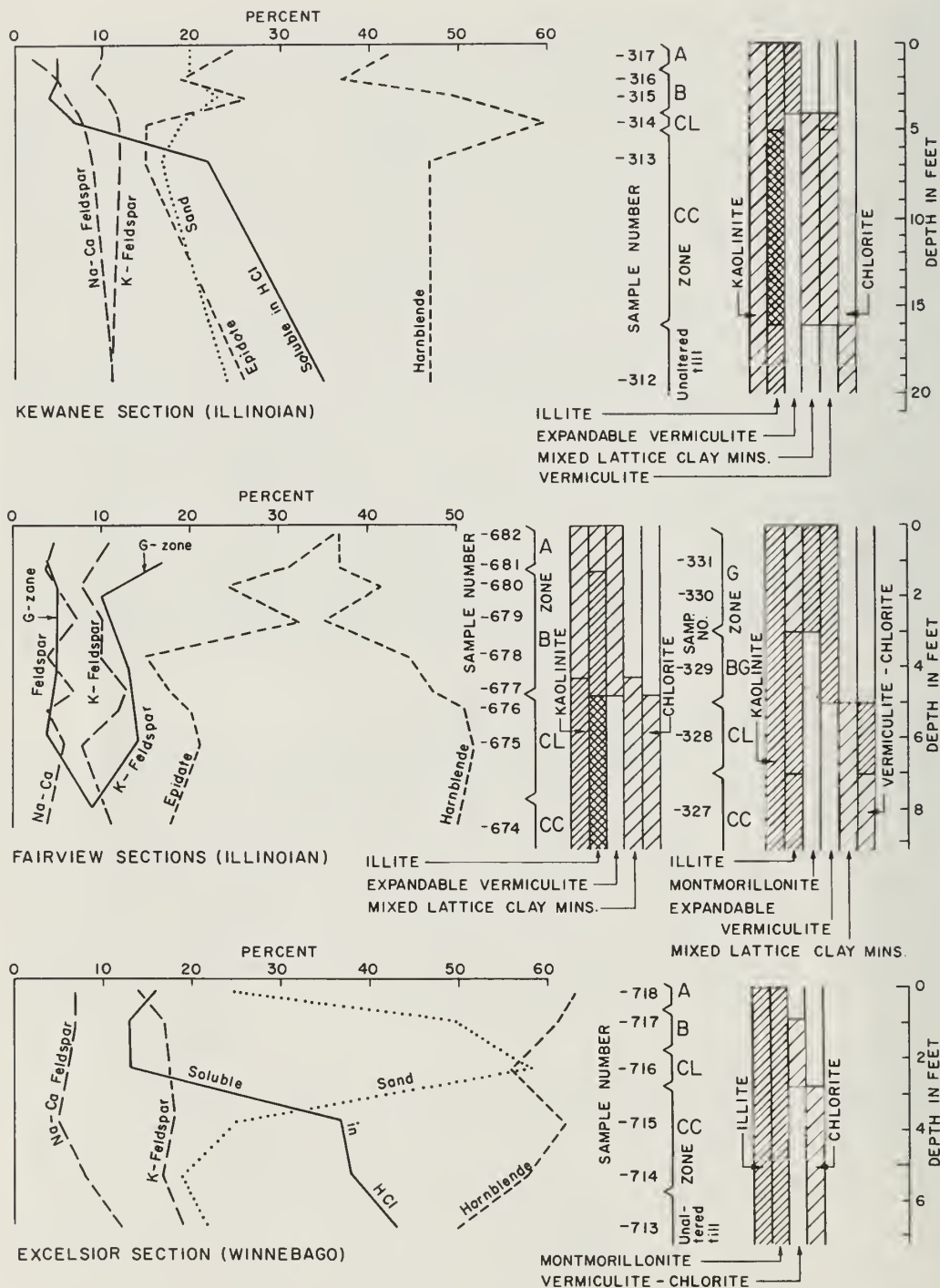
Fig. 3 – Values of selected mineral constituents in Kewanee, Fairview, and Excelsior sections. Sample locations are given in table 1, and quantities given in tables 2 and 3.

Most, if not all, of the feldspar depletion is of Na-Ca feldspars (figs. 2, 3). Assuming the K-feldspars to be constant, there is a depletion of 25 percent of Na-Ca feldspars in the B-zone and 31 percent in the A-zone. Compared with the average calcareous till, the accretion-gley shows a 42 percent depletion of Na-Ca feldspars but an increase of K-feldspars.

As is shown by the Kewanee section (fig. 3), the Na-Ca feldspars decrease progressively upward through the CL-, B-, and A-zones. However, this relationship does not obtain in the accretion-gley sections (fig. 4).

In contrast to the weathering profiles of the Illinoian till, the profiles on Winnebago (early Wisconsinan) till show relatively little depletion of feldspars except in the A-zone. The averages show 31 percent depletion in the A-zone but only 5 percent in the B-zone. The samples of accretion-gley on Winnebago till show a percentage of both Na-Ca and K-feldspars as high as that of the calcareous Winnebago till.

Clay Minerals

The clay mineralogy of all samples was determined by X-ray methods and the results are given in table 3. The terms chlorite, kaolinite, illite, and montmorillonite are used in the generally accepted sense. The terms vermiculite and vermiculite-chlorite, mixed-lattice clay minerals, and expandable vermiculite refer to a transitional series of alteration products, derived primarily from biotite-type micas and chlorite. Chlorite alters first to vermiculite-chlorite, even below the depth of carbonate leaching (Droste and Thoren, 1958), then to the partially expandable mixed-lattice stage, and finally to the expandable vermiculite stage. Biotite-type micas probably alter through a vermiculite stage to the expandable vermiculite stage. Examples of the major types of X-ray patterns are shown in figure 5.

This alteration sequence can be confirmed experimentally. The saturation of expandable vermiculite materials with magnesium chloride produces vermiculite that is not expandable with ethylene glycol.

The unaltered Illinoian till is characterized by the presence of illite, chlorite, and kaolinite, with or without primary montmorillonite. Unaltered Winnebago till consistently contains montmorillonite in addition to illite and chlorite and lacks kaolinite, whereas the unweathered tills of Woodfordian age, except in their outermost moraines in northern Illinois, are predominantly illite and chlorite and generally lack kaolinite and montmorillonite (fig. 5, sample 390).

The clay mineral assemblage in the CC- zone strongly resembles that in the unaltered till. However, in the profiles on Illinoian till (and in a few samples of till of Woodfordian age) some of the chlorite and biotite-type micas have been altered to the vermiculite-chlorite and mixed-lattice stages.

In the CL-zone on Illinoian till unaltered chlorite is not detectable, and the zone is characterized by vermiculite, vermiculite-chlorite, and mixed-lattice clay minerals (fig. 5, sample 314). The amount of these alteration products appears to increase upward through the zone, but illite appears to have approximately the same abundance as in the unaltered till.

The B-zone on Illinoian till is characterized by the absence of biotite-type micas and chlorite which have entirely altered to expandable vermiculite (fig. 5, sample 329). There is a significant decrease in illite, and the kaolinite appears unchanged. In the till of Woodfordian age the B-zone shows no loss of illite, and the alteration of biotite-type micas and chlorite has progressed only as far as the
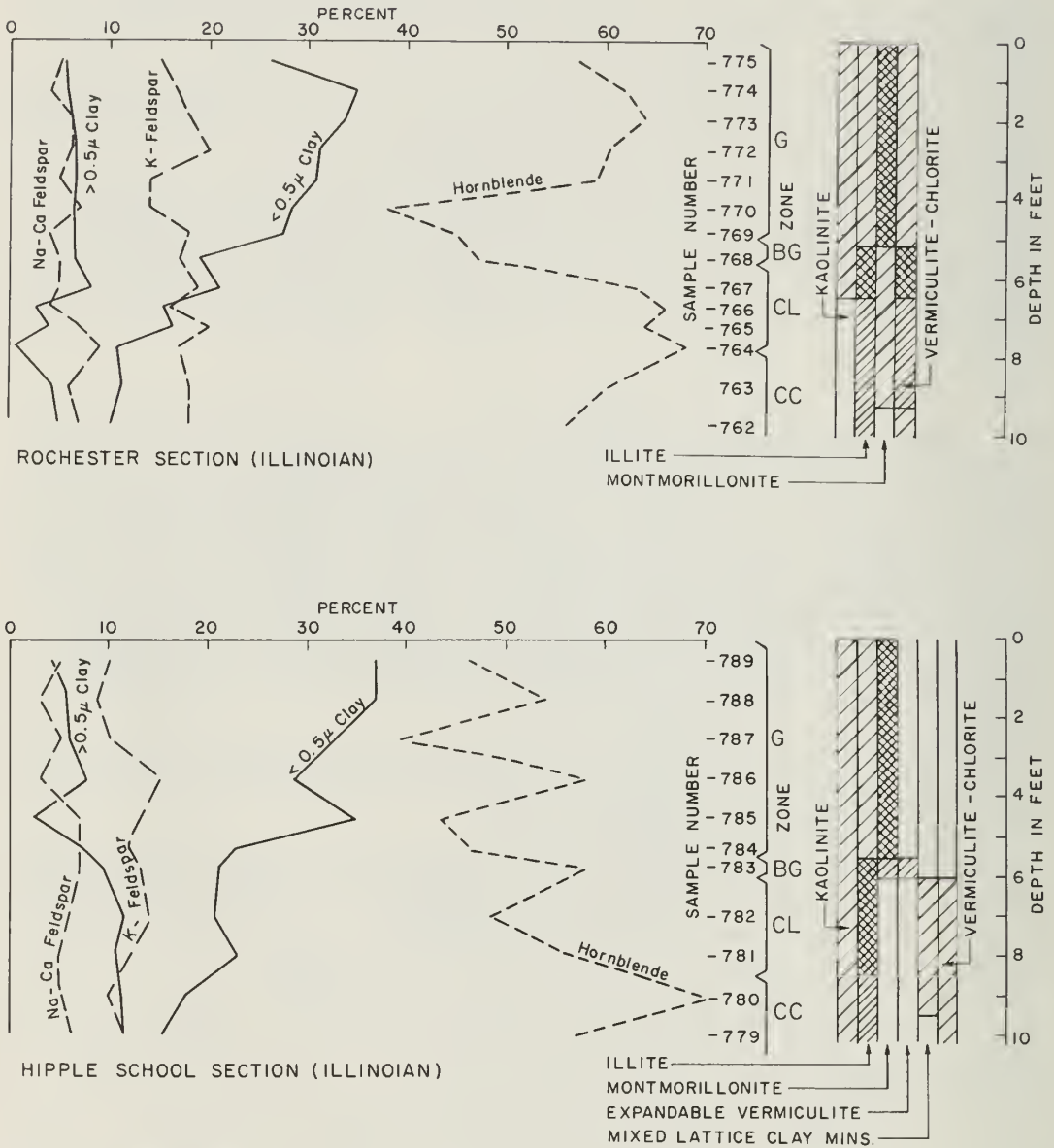
Fig. 4 – Values of selected mineral constituents and abundance of clay at
Rochester and Hipple School sections. Sample locations are given in table
1, and quantities given in tables 2 and 3.

vermiculite-chlorite and mixed-lattice stages. The B-zone on Winnebago till resembles, in general, that on Woodfordian, except for the presence of primary montmorillonite in the Winnebago.

The A-zone on Illinoian till resembles the B-zone but there appears to be some further decrease of illite.

The BG-zone on Illinoian till (fig. 5, sample 768) generally resembles the B-zone, except where overlain by accretion-gley. In such situations its clay mineral composition more nearly resembles that of the CL-zone.

The clay mineralogy of the G-zone (accretion-gley) that has accumulated on Illinoian till surfaces is strikingly different from that of the in situ profiles. The G-zone is characterized by a high content of montmorillonite, a low content of illite, and the presence of kaolinite (fig. 5, sample 769). Vermiculite or chlorite may or may not be present. In those sections where the samples are closely spaced it is apparent that, at the contact between the in situ weathered profile and the accretion-gley, the assemblage of clay minerals changes sharply without a transition zone (fig. 5, samples 768, 769). Accretion-gley generally rests directly upon the BG- or CL-zones. The presence of chlorite or vermiculite with montmorillonite demonstrates that the clay mineral assemblage could not have been produced by weathering in place. In the B-zone chlorite and vermiculite are absent, having been altered to expandable vermiculite. The clay mineral assemblage of accretion-gley is a physical mixture.
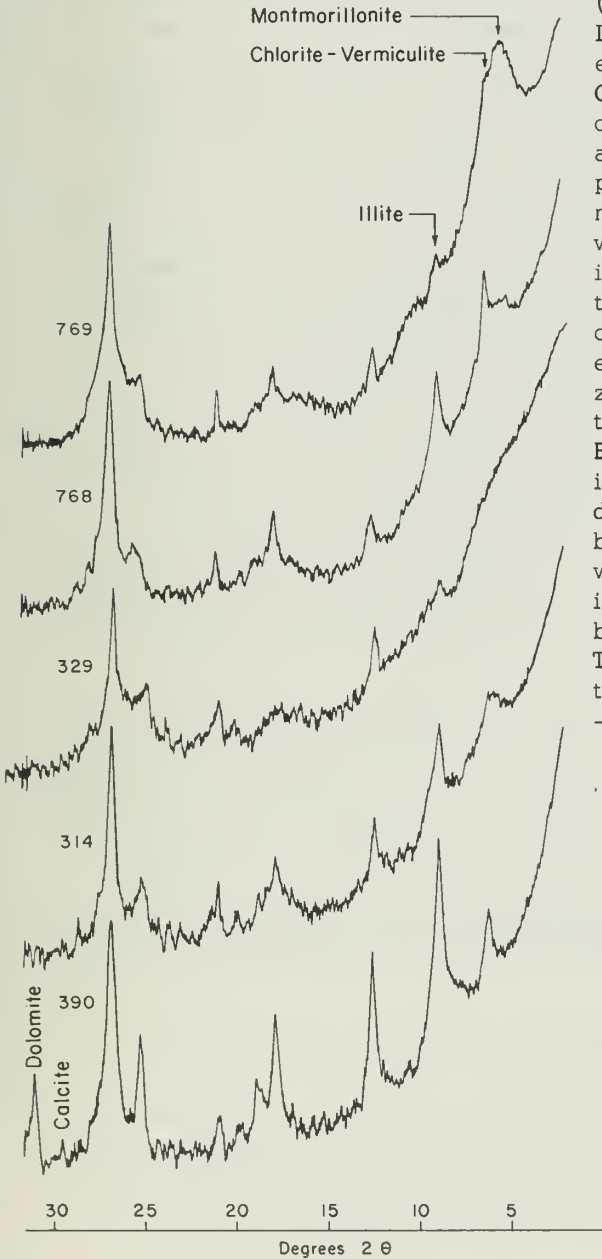
Fig. 5 – X-ray patterns of five typical samples.

Sample 769: Illinoian G-zone; montmorillonite, vermiculite, illite (weak), and kaolinite.

Sample 768: Illinoian BG-zone 6 inches below contact with Illinoian G-zone (769); vermiculite; illite and kaolinite.

Sample 329: Illinoian B-zone; expandable vermiculite, illite (weak), and kaolinite.

Sample 314: Illinoian CL-zone; illite, vermiculite-chlorite, mixed-lattice clay minerals, and kaolinite.

Sample 390: Woodfordian CC-zone; illite and chlorite.

Heavy Minerals

Even though heavy minerals generally constitute less than one percent of the very fine and fine sand fractions of the samples, their wide range in susceptibility to weathering renders them a gauge of the degree of alteration in the profiles. The relative resistance of the several heavy minerals has been a subject of continuing study, one to which particularly significant contributions have been made by Gravenor (1954), Ruhe (1956), and Brophy (1959).

Ruhe (1956) used the ratio of zircon plus tourmaline to amphiboles plus pyroxenes, and Brophy (1959) used the ratios of tourmaline plus zircon to hornblende and to garnet to indicate the degree of weathering. We have not used these methods because of the relatively low content of tourmaline and zircon in the samples, and because slight variations in grain size influence their abundance. The peak of abundance of tourmaline and zircon occurs in widely different size grades. A consideration of percentage of mineral depletion has appeared to be more useful in this study.

Based on an assumption of constancy of tourmaline and zircon, the average of the analyses of Illinoian profiles shows no depletion of hornblende in the CL- and BG-zones, 50 percent depletion in the B-zone, 62 percent in the A-zone, and only 21 percent in the G-zone. Assuming no loss of tourmaline, zircon, garnet, and epidote, the ferromagnesian minerals show no depletion in the CL-zone, 32 percent in the BG-zone, 35 percent in the B-zone, 47 percent in the A-zone, and 32 percent in the G-zone.

The only other mineral for which a consistent loss can be shown is garnet. Relative to tourmaline and zircon, the analyses (table 4) show a garnet depletion of 22 percent in the B-zone and 50 percent in the A-zone. However, the same comparison shows no loss of garnet in the G-zone. Increases in tourmaline, zircon, and epidote (fig. 2; table 2) are related largely to depletion of the hornblende and, to a lesser extent, of the garnet. Depletion of 50 percent of the hornblende and 15 percent of the garnet from the CC-zone on Illinoian till would produce a heavy mineral assemblage similar to that of the B-zone. Depletion of 60 percent of the hornblende and 40 percent of the garnet from the CC-zone would produce a heavy mineral assemblage similar to that of the A-zone.

The fact that epidote does not appear to be reduced in the weathering zones suggests that the weathering is not in an advanced stage. Goldich's (1938) analyses show that in mature weathering of granite gneiss the hornblende is eliminated before epidote in three of six samples, although there is four times as much hornblende as epidote in the fresh gneiss. In the most advanced stages of weathering the epidote also is largely eliminated.

The average of the much smaller number of samples from the Winnebago till shows a depletion rate among the heavy minerals that is comparable to that on the Illinoian. On the tills of Woodfordian age there appears to be only slight depletion of hornblende in the B-zone.

Grain Size

Clay

The B-zones of the weathering profiles on Illinoian till commonly contain 10 to 20 percent more clay-sized particles than are present in the unweathered till (Brophy, 1959, p. 17, 18), and the accretion-gleys contain a higher percentage (fig. 4; table 5). According to the gumbotil concept, the clay concentration is

largely derived from silicate decomposition in place, and the base of the B-zone represents the downward limit of essentially complete chemical weathering, leaving the B-zone as a residuum. The alternate interpretation attributes the increase in clay in the B-zone to illuviation, the clay being derived largely from weathering at the surface with only a minor proportion contributed by silicate decomposition within the B-zone.

The additional clay in the B-zone can come from several potential sources:

1) If the clay content of the original deposits is 20 percent, the leaching of the 25 percent of primary carbonates would, by reducing the volume, increase the clay content by 5 to 7 percent.

2) The residue, perhaps 10 percent of the limestone and dolomite, may add 1 to 2 percent to the clay content.

3) The disaggregation of shale fragments could, at least locally, make an important contribution to the clay content of the B-zone, but shale fragments commonly are not conspicuously abundant in the Illinoian drift and their disaggregation probably would not generally contribute more than 1 or 2 percent to the clay content.

4) The weathering of feldspars within the B-zone contributes slightly to the clay content. Although the sand and silt fractions are commonly 15 to 20 percent feldspar, weathering only locally reduces the total feldspars by more than 5 percent. The addition of clay from this source, therefore, probably would not average more than 1 or 2 percent.

5) Clay from the A-zone also is added to the B-zone by illuviation. This clay is derived partly from original clay and partly from decomposition of silicates, and is moved slowly downward by percolating water along the vertical planes of parting in the structural elements of the soil, along openings produced by plants and animals, and through intergranular openings. If average contributions are made from the other possible sources, illuviation need account for only one-fourth to one-half of the increase in clay content, perhaps 5 to 10 percent.

The clay and feldspars in 6 inches to 1 foot of original material would appear to be adequate to supply the illuviated clay in an average B-zone 3 to 5 feet thick.

Analyses of the percentage of clay in the $<0.5\mu$ size and total clay ($<2\mu$) were made for the Rochester and Hipple School sections and are shown in table 5 and figure 4. Comparable data for two in situ profiles developed on Illinoian till are given by Brophy (1959, p. 17, 18). Comparison of the two sets of data shows that the relation of fine clay to coarse clay in the accretion-gley is comparable to that in the mid-portion of in situ B-zones. The vertical relations, however, are different.

In the B-zone there is a decrease in fine clay upward through the upper B-zone and A-zone and a sharp decrease downward into the CL-zone. In the accretion-gley there is a suggestion of an upward increase in fine clay, but not in a smoothly progressive manner. The coarse clay fraction stays within a relatively small percentage range throughout all of the zones, although the Hipple School section suggests a decrease in coarse clay in the accretion-gley.

Sand

In general, the sand content of the CL-zone of the weathering profiles on the Illinoian till is close to the amount predictable by removal of the carbonates in the underlying CC-zone. In many profiles the highest percentage of sand occurs in the CL-zone or at the base of the B-zone. The amount of sand progressively decreases upward through the B-zone to the A-zone, where it increases again.

These relations are particularly well shown in the detailed mechanical analyses of the Effingham and Flamingo sections by Brophy (1959, p. 17, 18). Solubility determinations on his samples (table 1, samples 180-209) show the effect of loss of carbonates. In the Effingham section, the five calcareous samples average 35.3 percent sand and 17 percent carbonates. Leaching the carbonates should increase the sand to 42 percent in the leached material. The one sample of leached till (omitting sample E-8, which probably is from a crayfish boring) contains 40 percent sand, the one next higher in the transition zone at the base of the B-zone contains 40.9 percent. As the sand fraction contains a small proportion of carbonate minerals, the analyses suggest that the increase is closely related to the leaching of the carbonates.

The samples from the B-zone in the Effingham section show a continuous upward decline in sand content to 28.6 percent. As this is parallel to the upward increase in clay content, the sand decrease appears to be related almost entirely to clay illuviation.

Weathering profiles on Winnebago drift (early Wisconsinan) near Rockford (table 1, samples 705-712) show comparable variations in sand content, and the several samples of younger Wisconsinan (Woodfordian) drift also show that the increase in sand is related essentially to the solution of the carbonates.

According to the gumbotil concept of advanced silicate decomposition, the sand content should increase sharply at the base of the B-zone and further increase upward unless there is increasing solution of sand grains upward. The loss of sand grains by leaching seems unlikely as the remaining quartz grains are well rounded and show no evidence of solution etching.

The sand content of the gleys is generally lower and more variable than that in the developed profiles.

Pebbles

The decrease in abundance and size of pebbles in the gumbotils frequently is cited as evidence of the extreme degree of weathering. The observations of Kay and Apfel (1929) for Nebraskan gumbotil and unleached till at two localities in Iowa, based on samples of 100 pebbles each, are as follows:

Size of Pebbles - Compiled from Kay and Apfel (1929)

	Smallest		Average		Largest	
	mm	cc	mm	cc	mm	cc
Locality 1						
Gumbotil	2	.008	8 x 5	.260	24 x 14 x 10	3.36
Unleached	3.4	.039	17 x 15 x 10	2.55	62 x 45 x 17	47.43
Locality 2						
Gumbotil	2 x 1.5	.006	3	.027	10 x 7 x 5	.350
Unleached	3 x 2	.014	15 x 10 x 7	1.05	55 x 35 x 30	57.75

Although comparable analyses have not been made on Illinois samples, the accretion-gleys on Illinoian till appear to show the same relative variation in size of pebbles. Interpretation of the materials previously called gumbotil as accretion deposits accounts for the absence of larger pebbles because they tend to remain in lag concentrates on the bordering slopes.

In the in situ profiles the decrease in abundance of larger pebbles in the B-zone generally is apparent and is related to several causes. Although the percentage of limestone and dolomite pebbles in the unweathered till increases rapidly as the size of the pebbles increases, the carbonate pebbles are entirely removed in the B-zone. The large pebbles, cobbles, and boulders originally in this zone were close to the surface and subject to physical as well as chemical disaggregation. Some of them may have been moved to the surface by frost action. Cobbles and boulders, though scarce, are present in the B-zone, and in many exposures they appear to be as prevalent as in a comparable thickness of the unweathered till.

Composition of Pebbles

The abundance of siliceous pebbles (largely quartz, chert, and quartzite) in gumbotil has been used as evidence that gumbotil is a residuum from weathering of the till. Pebble counts by Kay and Apfel (1929) and others in Iowa are among the most extensive available and are summarized as follows:

Composition of Pebbles (in percent) – Compiled from Kay and Apfel (1929)

	NEBRASKAN			KANSAN		
	Calcareous	Leached	Gumbotil	Calcareous	Leached	Gumbotil
Av. thickness of zone (ft)		2	8		5.5 5.5	11
No. samples	14	3	sev.	21	sev. sev.	7
Limestone and dolomite	44.6			34	3	
Shale	1.0				2	
Sandstone	1.9			2	3 1.0	.5
Quartz	3.3	14	36.75	2	7 16.8	48.5
Chert	4.3	15	21.25	9	16 16.5	31.8
Quartzite	5.7	13	20.25	5	15 8.0	6.8
Granite	13.3	19	8.25	14	17 20.3	7.8
Basalt-greenstone	25.1	29	11.00	27	19 25.5	2.9
Unidentified and others	.8	10	2.50	7	18 11.9	1.7

The pebble counts listed by Kay and Apfel (1929) show that quartz, chert, and quartzite pebbles compose only 13 percent of the pebbles in calcareous Nebraskan till in Iowa, but they compose 78 percent in the overlying gumbotil. Comparably, they compose 16 percent of the pebbles in calcareous Kansan till in Iowa, and 87 percent in the overlying gumbotil. If it is assumed that the pebble counts are an accurate index to the gross mineralogical changes in in situ profiles, the amount of volume reduction of the till and the amount of depletion of normally resistant siliceous materials seems unreasonably large. For example, if no quartz pebbles were lost in forming the Nebraskan gumbotil, more than 96 percent of the granite, basalt, and greenstone, 58 percent of the chert, and 75 percent of the quartzite pebbles were eliminated by weathering. For the Kansan gumbotil, the loss is even greater — 99.6 percent of the basalt and greenstone, 98 percent of the granite, 94 percent of the quartzite, and 86 percent of the chert.

If we use Kay and Apfel's (1929) estimates for average thickness of gumbotil and assume that pebbles make up 3 percent of the gumbotil, 6 percent of the leached till, and 5 percent of the calcareous till, it is possible to calculate the thickness of calcareous till that would have been reduced by weathering to provide the siliceous material described as occurring in the gumbotil. Fifty-three feet of calcareous till would be required to provide the quartz pebbles in the Nebraskan gumbotil, plus an additional 10 feet needed to account for the leached till. Thus 63 feet of calcareous till would have been reduced to 10 feet of material.

Because of the greater thickness given for the Kansan gumbotil, the results of such a calculation are more extreme. There would have been about 200 feet of calcareous Kansan till reduced to the $16\frac{1}{2}$ feet of existing material. Calculations based on chert and quartzite content indicate that 25 to 35 feet of calcareous till would have been needed to provide the quantities of these rocks found in the gumbotil and leached zone on both the Nebraskan and Kansan drifts of Iowa.

The weathered zones represented in these analyses from Iowa appear to be comparable to those on Kansan and Illinoian drift in Illinois. In Illinois the moderate depletion of feldspars, hornblende, and other silicates in the weathered zones on Illinoian till is exceeded only slightly by that shown by the few samples of weathered Kansan till in Illinois (table 2).

Several factors may account for the appearance of exceptionally high concentration of siliceous materials in the gumbotils. As many of the gumbotils are deposits of accretion-gley, they are not derived directly from the underlying till. In these cases, the pebbles are concentrated largely from the most weathered material in the uppermost parts of the profiles on adjacent gentle slopes, and the thickness of accretion-gley deposits is not related to the degree of weathering. The scattered occurrence of relatively fresh granite and coarse-grained basic igneous pebbles in the accretion deposits indicates that unweathered materials are at least occasionally incorporated in the deposit. However, the fact remains that near the surface of the deeply weathered Kansan and Nebraskan drift the degree of concentration of siliceous materials may be considerably greater than on Illinoian drift.

The appearance of exceptionally high concentration of siliceous pebbles results from the great variation in pebble composition that occurs with variation in size of pebbles. The pebbles in the gumbotil are generally less than one inch in diameter. In calcareous till, quartz pebbles of this size are commonly more abundant than other siliceous pebbles or igneous and metamorphic pebbles. In contrast, quartz pebbles are scarce in sizes above one inch, the sizes that dominate the collections from the calcareous drift.

The unweathered Illinoian till in Illinois contains approximately 40 percent quartz, 25 percent calcite and dolomite, 15 percent feldspar, 15 percent clay minerals, and 5 percent other silicates and oxides. The depletion studies suggest that a loss of all the carbonates, not over a third of the feldspar, less than 10 percent of the clay, and perhaps as much as half the other minerals is the maximum for the most weathered material at the top of the profile. This suggests that the total loss is perhaps about a third of the volume of the interval above the calcareous zone — a shrinkage loss that might produce a maximum lowering of 3 to 5 feet on the Illinoian till plain where it is underlain by in situ weathering profiles.

CONCLUSIONS

Two distinctly different genetic types of material characterize the weathered upper part of the glacial deposits of the till plains of Illinois (Frye, Shaffer, Willman, and Ekblaw, 1960). These are 1) in situ profiles of weathering that have developed downward in glacial till, and 2) accretion-gley deposits of somewhat weathered, generally fine-textured materials derived from a nearby source that have accumulated slowly in shallow, initial depressions on the till plain.

The mineralogy and origin of weathering profiles developed in place on the tills of Illinois were studied. These studies led us to several conclusions.

1) Maximum degree and depth of mineral alteration occur where there is moderate surface drainage and the parent material has moderate to good permeability.

2) Oxidation and initial alteration of chlorite and biotite to vermiculite-chlorite and vermiculite appear to be the earliest weathering effects because they are recognizable at the greatest distances below the surface (at least 15 to 20 feet in Illinoian till).

3) The leaching of carbonate minerals causes the major loss of volume resulting from chemical weathering, and in thick profiles calcite is leached to an appreciably greater depth than dolomite.

4) The most sensitive indication of weathering is alteration of clay minerals. In profiles developed in Illinoian till the alteration sequence is from chlorite and biotite-type micas through vermiculite-chlorite, vermiculite, mixed-lattice clay minerals to expandable vermiculite; kaolinite is unaffected (and may be augmented) and muscovite-illite persists upward into the A-zone.

5) Of the major constituents in the sand sizes, quartz and K-feldspars appear to be unaffected chemically, but a significant amount of the Na-Ca feldspars have been decomposed in the upper part of the profile, particularly in the A-zone. Of the heavy minerals, the ferromagnesians have been extensively decomposed at the top of the profile.

6) The B-zone is characterized by a marked increase in the percentage of the <0.5-micron clay. As analyses of the minerals of the sand-size fraction preclude the possibility that much of this added fine clay developed in place from decomposition of feldspars and other minerals, we judge that most of it was developed in the A-zone by alteration of clay minerals and some decomposition of Na-Ca feldspars and ferromagnesian minerals, and moved progressively downward as fine clay into the B-zone. This downward movement probably was greatest along the vertical planes of the soil structure and along openings made by plants

and animals. The available data suggest that clay coarser than 0.5 micron was not subject to such downward movement. Downward movement of water through such micro-avenues also had an influence on differential alteration of minerals in the B-zone (Allen, 1959).

The accretion-gley deposits differ from developed profiles in structure, pebble content, texture, and field relations. Mineralogical studies of accretion-gley indicate the following differences from the in situ profiles.

1) Accretion-gleys, in contrast to the progressive alteration of clay minerals observable in developed profiles, display a mixture of clay minerals throughout their entire thickness that terminates sharply at the base.

2) Accretion-gleys are typified by an abundance of montmorillonite generally not observed in profiles developed in place on Illinoian till. The origin of this montmorillonite is not adequately understood. As the loesses of this region contain abundant montmorillonite, the presence of montmorillonite in the accretion-gley has been ascribed to an increment of loess. However, according to other mineralogical data and field relationships, the loess, if present, must be in minor amount.

3) The mineralogy of the accretion-gley sand fraction indicates an even less advanced stage of weathering than the B- and A-zones of developed profiles.

4) The mineral composition of the accretion-gleys, as well as their texture and pebble content, can be accounted for by derivation from gentle slopes adjacent to the shallow depressions in which they accumulated.

It is apparent from the genetic data that the thickness of accretion-gleys is of little significance as a time indicator.

The original description of gumbotil postulated development by progressive downward weathering of till, but described a physical deposit that can be only the slowly accumulated material called accretion-gley. Furthermore, the degree of mineral decomposition ascribed to these gumbotils is far beyond the degree of decomposition that has been determined in either the in situ weathering profiles or the accretion-gleys.

It is our judgment that the term "gumbotil" has not been used in a sufficiently precise sense to justify its retention as a scientific term and that it should be used only in a general sense to refer to those plastic and sticky surficial clays resting on till. Accretion-gleys can be distinguished in the field and laboratory, and in situ profiles of weathering on till can be described by reference to the defined zones.

Table 1. - Description of Samples

Sample no.	Location $\frac{1}{4}$ sec. T. R., County	Age of parent material	Zone of profile	Thickness of zone (ft.)	Position in zone (ft. below top)	% of sand in the -2 mm. size fraction	% of the -2 mm. size fraction soluble in HCl
1	SW NE SE, 20-3N-8W, Madison	Kansan	CC	4+	2	33	23
2	do.	do.	CL	1.2	0.8	41	9
3	do.	do.	B	1.3	0.5	28	9
13	SW SE NE, 31-3N-6W, Madison	Illinoian	B	3+	1.5	38	1
16	do.	do.	B	2	1	42	16
24	SE SW NE, 10-5N-10W, Madison	do.	B	2	2	34	7
26	do.	do.	CC	23	8	30	9
57	SE SW, 13-4S-4W, Pike	do.	Bᶜ			39	5
60	SW SE, 9-4S-4W, Pike	do.	B	3+	1	49	11
61	SE SW, 13-4S-5W, Pike	Kansan	CL	5	3	57	4
94	NW NW NE, 23-18N-7W, Menard	Illinoian	CC	10	8	39	27
97	Cen. E line, 11-18N-11W, Cass	do.	CC		2	57	26
98	do.	do.	B	3	1.5	29	5
113	NE SE NE, 10-6N-5E, Fulton	do.	CC	5+	5	37	20
114	do.	do.	CL	1	1	60	5
119	SW SW NE, 31-7N-6E, Peoria	Kansan	unox.			25	22
120	SW SW NE, 31-7N-6E, Peoria	do.	CC	29	26	34	27
123	do.	do.	CC	29	9	28	23
124	do.	do.	B	4	2	57	9
125	do.	Illinoian	CC	29	26	21	25
126	do.	do.	CC	29	1	32	33
131	Cen.,31-26N-3W, Tazewell	do.	CC	5+	3	19	29
132	do.	do.	G	1.5	1	58	6
138	do.	Shelbyville	unox.			18	33
139	SE NW SW, 12-26N-4W, Tazewell	Bloomington	CC	10+	1	42	35
145	SW NW NE, 1-25N-2E, McLean	Shelbyville	CC	8	2	36	33
146	do.	Bloomington	CC	3	1	26	31
148	do.	Normal	CC	3	2	12	26
170	NW NE NE, 31-36N-12E, Cook	Valparaiso	CC	(Sample 102, R.I. 79)*			
171	NW NE SW, 9-34N-4E, LaSalle	Bloomington	CC	(Sample 104, R.I. 79)*		58	13
172	NE SE NW, 10-5N-3W, Bond	Illinoian	CC	(Sample 105, R.I. 79)*		44	26
173	SE SE NW, 36-18N-11W, Cass	Illinoian	CC	(Sample 106, R.I. 79)*		33	28
180	NW SW NW, 31-8N-3E, Fulton	do.(F-1)	unox.	6+	5.5	27	24
181	do.	do.(F-2)	unox.	6+	3	23	27
182	do. (Samples 180-251 were col-	do.(F-3)	unox.	6+	0.5	18	22
	lected by Brophy (1959).						
183	do. His sample nos. appear	do.(F-4)	CC	9.7	9	14	30
184	do. in parentheses in the age	do.(F-5)	CC	9.7	4.5	17	24
185	do. column. New data are	do.(F-6)	CC	9.7	0.5	19	23
186	do. given here.)	do.(F-7)	CL	2.5	1.5	28	7

Table 1. - Continued

Sample no.	Location ¼ sec. T. R., County	Age of parent material	Zone of profile	Thickness of zone (ft.)	Position in zone (ft. below top)	% of sand in the -2 mm. size fraction	% of the -2 mm. size fraction soluble in HCl
188	do.	do.(F-9)	B	4	3.5	20	
189	do.	do.(F-10)	B	4	2.5	14	
190	do.	do.(F-11)	B	4	1.5	12	7
191	do.	do.(F-12)	B	4	1	11	
192	do.	do.(F-13)	B	4	0.5	11	
195	Cen. 6-7N-6E, Effingham	do.(E-1)	unox.	7.5+	6	32	28
196	do.	do.(E-2)	unox.	7.5+	3	31	24
197	do.	do.(E-3)	unox.	7.5+	0.5	38	29
198	do.	do.(E-4)	CC	1.6	1	35	23
199	do.	do.(E-5)	CC	1.6	0.5	39	19
200	do.	do.(E-6)	CL	1	0.8	40	8
201	do.	do.(E-7)	B	5.1	4	41	
202	do.	do.(E-8)	B	5.1	3.5	40	
203	do.	do.(E-9)	B	5.1	2.5	33	5
204	do.	do.(E-10)	B	5.1	2	31	
205	do.	do.(E-11)	B	5.1	1	29	
206	do.	do.(E-12)	B	5.1	0.5	29	
207	do.	do.(E-13)	A	1.9	1.5	31	
208	do.	do.(E-14)	A	1.9	1	31	
209	do.	do.(E-15)	A	1.9	0.5	30	
239	NW SW NW, 31-8N-3E, Fulton	do.(F-2)	unox.	6+	3		
240	do.	do.(F-2)	unox.	6+	3		
241	do.	do.(F-5)	CC	9.7	4.5		
242	do.	do.(F-5)	CC	9.7	4.5		
245	do.	do.(F-11)	B	4	1.5		
246	do.	do.(F-11)	B	4	1.5		
247	Cen., 6-7N-6E, Effingham	do.(E-1)	unox.	7.5	6		
248	do.	do.(E-6)	CL	1	0.8		
249	do.	do.(E-7)	B	5.1	4		
250	do.	do.(E-11)	B	5.1	1		
251	do.	do.(E-13)	A	1.9	1.5		
291	NE NE, 22-23N-9E, Ogle	Winnebago	G	4+	3	11	7
292	NE NE, 22-23N-9E, Ogle	Winnebago	G	4+	1	14	7
293	NE NW NW, 36-27N-6E, Stephenson	Winnebago	G	2+	2	28	9
294	NW NW SE, 9-23N-8E, Ogle	Winnebago	G	12+	2	12	6
312	SW NW NW, 15-15N-5E, Henry	Illinoian	unox.	10	3	24	35
313	do.	do.	CC	12	2	17	21
314	do.	do.	CL	0.7	0.5	19	7
315	do.	do.	B	2.5	1.5	23	4
316	do.	do.	B	2.5	0.5	20	5
317	do.	do.	A	2.5	1.7	20	5
318	do.	do.	A	2.5	0.5	14	11

Table 1. - Continued

Sample no.	Location ¼ sec. T. R., County	Age of parent material	Zone of profile	Thickness of zone (ft.)	Position in zone (ft. below top)	% of sand in the -2 mm. size fraction	% of the -2 mm. size fraction soluble in HCl
320	NE NE SE, 26-15N-5E, Henry	Illinoian	G	5	2	16	9
327	SE NE NW, 36-8N-2E, Fulton	do.	CC	8	1	30	18
328	do.	do.	CL	2	1	25	11
329	do.	do.	BG	2	1	41	11
330	do.	do.	G	3	2	15	6
331[a]	do.	do.	G	3	1	35	7
334	NW SW NE, 5-14N-4W, Sangamon	Illinoian	G	8	2		3
335	NE SE SE, 4-14N-4W, Sangamon	do.	CC	5	4	29	29
336	do.	do.	CL	4	3	46	5
337	do.	do.	B	3	2.5	22	6
338	do.	do.	B	3	0.5	34	7
339	do.	do.	BG	2.5	1.5	20	11
340	do.	do.	A	3.5	2.5	21	6
344	SE NW SE, 23-25N-6E, McLean	Cropsey	CC	4+	0.5	8	33
345	SE NW SE, 23-25N-6E, McLean	do.	B	1.5	0.5	11	14
348	NW NE NW, 9-23N-4E, McLean	Normal	B			23	14
357	NW SE NW, 6-21N-4W, Mason	Illinoian	CC	10	2	28	21
358	do.	do.	B	1.5	0.8	23	11
365	NE SW SE, 12-25N-5W, Tazewell	Illinoian	CC	8	4 •	22	28
369	NW SE SW, 18-15N-10E, Bureau	do.	CC	20	18	19	26
372	SE SE SW, 15-16N-10E, Bureau	Arlington	CC	10+	2	20	39
374	SW SE SE, 22-16N-10E, Bureau	Illinoian	unox.	5+	2	37	32
376	do.	do.	CC	7	2	33	29
377	do.	do.	CL	2.5	1	32	6
378	do.	do.	B	1.5	0.8	17	12
384	SW SE SE, 27-16N-10E, Bureau	Bloomington	CC	4	3	23	34
390	SE SE SW, 36-34N-4E, LaSalle	Marseilles	CC	10	3	7	39
391	SW SW SW, 14-34N-8E, Grundy	Minooka	CC	3+	2	9	40
394	SW SW SW, 5-36N-12E, Cook	Valparaiso	CC	5+	1	7	30
395	do.	do.	B	1	0.5	12	15
400	SW SW SW, 1-37N-12E, Cook	Tinley	CC	5+	2	6	29
401	NW SW SW, 19-43N-9E, McHenry	W. Chicago	CC	4+	2	34	48
402	SW SW NE, 29-43N-8E, McHenry	Bloomington	CC			22	42
403	do.	Gilberts	CC			33	38
404	do.	Marseilles	CC			6	31
405	SW SW NW, 12-44N-5E, McHenry	Marengo	CC	5+	2	26	45
407	NE NW NE, 28-46N-17E, McHenry	W. Chicago	CC	3	1	38	48
408	SW NW SW, 1-46N-5E, Boone	Shelbyville	CC	1+	1	25	38
409	do.	do.	CL	0.5	0.2	39	28
410	do.	do.	B	1	0.5	40	10
411	NE SW NW, 32-46N-3E, Boone	Winnebago	CC	7+	1	40	40
412	do.	do.	CC	7+	0.1	49	16
413	do.	do.	B	2.5	0.5	54	5
415	SE NE SE, 11-46N-2E, Winnebago	Winnebago	CC	10+	1	49	34

Table 1. - Continued

Sample no.	Location ¼ sec. T. R., County	Age of parent material	Zone of profile	Thickness of zone (ft.)	Position in zone (ft. below top)	% of sand in the -2 mm. size fraction	% of the -2 mm. size fraction soluble in HCl
416	SE NE SE, 11-46N-2E, Winnebago	Winnebago	CL	1	0.5	33	8
417	do.	do.	B	2	0.5	53	10
421	NE SW SW, 5-26N-10E, Winnebago	do.	CC	2+	1	21	65
422	do.	do.	B	1.5	0.5	42	10
431	SW SW SW, 5-28N-6E, Stephenson	Winnebago	CC	5	2	11	46
601	NW SW SW, 5-1N-1W, Schuyler	Kansan	CC	10+	10	24	18
602	do.	do.	CC	10+	1	14	17
603A	do.	do.	CL	3	2.5	29	12
603B	do.	do.	B	3.5	3	35	18
603C	do.	do.	B	3.5	1.5	35	20
603D	do.	do.	B	3.5	1	28	20
603E	do.	do.	B	3.5	0.5	27	11
619	SW SW NW, 23-1N-1W, Schuyler	Illinoian	CC	2	2	35	17
621	do.	do.	CL	6	4	32	10
622	do.	do.	B	2	1	13	16
674[b]	SE NE NW, 36-8N-2E, Fulton	Illinoian	CC	4+	1	24	18
675[c]	do.	do.	CL	3	1.5	20	12
676	do.	do.	CL	3	0.5	34	13
677	do.	do.	B	3.5	3.5	19	14
678	do.	do.	B	3.5	2.5	15	16
679[d]	do.	do.	B	3.5	1.5	15	14
680	do.	do.	B	3.5	0.5	11	12
681	do.	do.	A	1.2	1.2	10	10
682[e]	do.	do.	A	1.2	0.2	10	8
687	Cen., 31-26N-3W, Tazewell	Illinoian	CC	5+	1	22	24
688	do.	do.	CL	1.5	1	23	2
689	do.	do.	BG	1.5	1.2	20	5
690	do.	do.	BG	1.5	0.2	20	3
691	do.	do.	G	1.5	0.8	14	5
705	Cen. E line, 13-27N-11E, Winnebago	Winnebago	unox.	7+	6	47	36
706	do.	do.	CC	3	1	41	23
707	do.	do.	CL	2	1	55	12
708	do.	do.	B	3	3	53	13
709	do.	do.	B	3	2	49	15
710	do.	do.	B	3	1	48	13
711	do.	do.	B	3	0.2	42	13
712	do.	do.	A	0.7	0.4	44	10
713	NW SW SE, 9-28N-6E, Stephenson	Winnebago	unox.	2+	1	22	43
714	do.	do.	CC	3	2.5	19	38
715	do.	do.	CC	3	1	25	37
716	do.	do.	CL	1	0.5	58	13
717	do.	do.	B	1.5	0.8	50	13
718	do.	do.	A	0.5	0.3	25	16

Table 1. - Continued

Sample no.	Location ¼ sec. T. R., County	Age of parent material	Zone of profile	Thickness of zone (ft.)	Position in zone (ft. below top)	% of sand in the -2 mm. size fraction	% of the -2 mm. size fraction soluble in HCl
726	NE cor., 10-22N-10E, Ogle	Shelbyville	CC	3+	2.5	27	36
727	do.	do.	CC	3+	0.5	29	31
728	do.	do.	B	1.5	0.5	39	13
750	NE cor. NW, 3-14N-4W, Sangamon	Illinoian	CC	3+	2	25	30
751	do.	do.	CL	2	1.8	47	11
752	do.	do.	G	5	4	43	1
753	do.	do.	G	5	2.5	32	15
754[f]	do.	do.	G	5	0.5		16
762[f]	NE cor. NW, 3-14N-4W, Sangamon	Illinoian	CC	3+	2	31	29
763	do.	do.	CC	3+	1	40	14
764	do.	do.	CL	2	2	52	6
765	do.	do.	CL	2	1.5	47	7
766	do.	do.	CL	2	1	46	8
767	do.	do.	CL	2	0.5	40	10
768	do.	do.	BG	0.5	0.3	41	10
769	do.	do.	G	5	4.7	29	10
770	do.	do.	G	5	4	37	10
771	do.	do.	G	5	3.3	32	10
772[g]	do.	do.	G	5	2.6	21	5
773	do.	do.	G	5	1.9	20	14
774	do.	do.	G	5	1.2	22	14
775[h]	do.	do.	G	5	0.5	32	13
779[h]	NW SW SW, 8-7N-3E, Fulton	Illinoian	CC	8+	1.5	18	21
780	do.	do.	CC	8+	0.5	15	16
781	do.	do.	CL	2.5	2	27	10
782	do.	do.	CL	2.5	1	21	10
783	do.	do.	BG	0.5	0.3	31	10
784[i]	do.	do.	G	5.5	5.2	33	11
785[i]	do.	do.	G	5.5	4.5	28	9
786	do.	do.	G	5.5	3.5	31	10
787[j]	do.	do.	G	5.5	2.5	34	11
788[j]	do.	do.	G	5.5	1.5	39	8
789	do.	do.	G	5.5	0.5	20	14
791	do.	do.	B	3	2.5	37	12
792	do.	do.	B	3	1	32	9

* Willman (1942).

In total sample:

[a] Na_2O = 1.04%; K_2O = 1.70%.

[b] Na_2O = 0.89%; K_2O = 2.35%.

[c] Na_2O = 0.95%; K_2O = 2.64%.

[d] Na_2O = 0.67%; K_2O = 1.70%.

[e] Na_2O = 1.23%; K_2O = 1.97%.

In total sample:

[f] Na_2O = 0.64%; K_2O = 2.32%.

[g] Na_2O = 0.75%; K_2O = 2.35%.

[h] Na_2O = 0.90%; K_2O = 2.20%.

[i] Na_2O = 0.67%; K_2O = 1.68%.

[j] Na_2O = 0.60%; K_2O = 1.45%

Table 2. - Heavy and Light Mineral Analyses (Carbonate-free Basis)

Sam-ple no.	.062-.250 fraction[a] %	Heavy minerals in fraction %	Opaque heavy minerals		Transparent heavy minerals (percent)							Light minerals (percent)			
			Black %	Others %	Tour-ma-line	Zir-con	Gar-net	Epi-dote	Horn-blende	Other amphiboles, pyroxenes	Others	Quartz	K-feld-spar	Na-Ca feld-spar	Others
1	19	0.90	5	20	4	2	14	12	67	3	2	67	20	6	7
2	24		27		4	2	24	15	31	11	13	76	12	7	5
3	19		37		7	6	23	12	26	6	23	72	15	7	6
13	17		48		3	9	21	32	15	1	15	72	17	3	8
16	26		57			12	31	40	8	6	0	81	12	4	3
24	22		36		5	5	14	20	27	8	21	77	14	8	1
26	20		29		5	10	27	9	28	2	19	81	6	7	6
57	26		43		6	6	10	44	19	6	9	78	10	6	6
60	37		50		17	12	4	44	4	7	12	83	8	4	5
61	37		43		12	18	13	21	18	3	15	76	13	6	5
94	22	0.74	16	4	4	3	17	19	36	15	6	68	17	5	10
97	24	0.71	10	10	1	3	13	19	60	4	0	70	18	9	3
98	12	0.94	21	11	1	1	31	18	44	1	4	76	14	4	6
113	16	1.6	13	20	1	4	16	20	55	3	1	70	10	5	15
114	22	0.68	14	14	5	3	7	27	57	0	1	81	14	4	1
119	13	1.60	15	13	3	1	17	28	42	6	3	71	15	7	7
120	14	1.90	10	44			11	39	44	4	2	73	11	7	9
123	15	1.5	17	22	7	2	15	28	45	0	3	77	15	7	1
124	18	0.64	30	11	3	3	8	36	36	8	6	80	11	3	6
125	11	1.30	39	21	7	1	21	16	36	11	8	81	13	5	1
126	12	1.70	40	35	6	2	6	29	37	10	10	70	17	7	6
131	11	2.20	29	28	5	1	13	24	40	8	9	72	15	8	5
132	12	0.33	18	14	9	1	8	30	40	4	8	88	6	3	3
138	16	1.50	10	31	2	2	12	29	51	2	8	75	16	7	2
139	17	0.61	15	12	1	3	20	18	57	1	0	77	17	6	0
145	15	1.30	11	20	1	1	5	25	66	1	1	77	15	7	1
146	11	1.10	18	19	1	9	5	23	53	3	6	72	20	8	0
148	7	0.45	16	13	1	3	14	14	63	3	2	73	19	7	1
170	6	1.60	16	3	1	1	7	24	63	3	1				
171	34	1.20	13	7	1	2	21	36	34	2	4				

(Heavy mineral data on Samples 180 to 251 are reported by Brophy [1959])

Sample															
172	23	1.50	26	10	2	5	14	34	39	3	3				
173	18	1.90	17	16	–	2	13	33	48	3	1				
180	6 b											71	15	7	7
181	10 b											72	13	7	8
182	6 b											74	13	7	6
183	4 b											72	9	7	12
184	6 b											79	9	6	6
185	8 b											79	10	7	4
186	6 b											72	12	6	10
188	4 b											74	14	6	6
189	3 b											78	8	8	6
190	3 b											70	17	7	6
191	3 b											79	8	3	10
192	3 b											78	10	4	8
195	8											72	14	10	4
196	8 b											66	15	11	8
197	8 b											65	17	13	5
198	10 b											73	15	4	8
199	8 b											71	14	12	3
200	9											75	15	7	3
201	7 b											72	13	9	6
202	8 b											74	14	7	5
203	8 b											78	13	5	4
204	6 b											80	13	5	2
205	5											81	12	6	1
206	5 b											80	13	5	2
207	6 b											75	14	8	3
208	6 b											79	11	5	5
209	6 c											74	15	7	4
239	9 c											79	8	5	8
240	1 d											85	5	5	5
241	6 c											74	13	7	6
242	3 d											81	7	5	7
245	4 d											75	13	2	10
246	4 d											80	7	3	10
247	d											73	10	5	12
248	d											82	9	3	6

Table 2. - Continued

Heavy-mineral columns "Tourmaline" through "Others" are Transparent heavy minerals (percent): the "Other amphiboles, pyroxenes" and final "Others" belong to this group. "Quartz" through the final "Others" are Light minerals (percent).

Sample no.	.062–.250 fraction[a] %	Heavy minerals in fraction %	Opaque Black %	Opaque Others %	Tour-maline	Zircon	Garnet	Epidote	Horn-blende	Other amphiboles, pyroxenes	Others (transparent)	Quartz	K-feldspar	Na-Ca feldspar	Others (light)
249	d														
250	d														
251	d														
291	8	0.54	11	17	3	5	17	25	42	8	-	82	8	3	7
292	10	0.35	22	19	8	12	22	23	33	2	-	88	7	2	3
293	21	0.22	26	23	-	5	11	29	51	3	1	84	8	4	4
294	7	0.55	31	12	3	7	20	33	35	2	-	70	22	7	-
312	6[e]	2.10	4	47	2	2	6	26	47	4	13	74	19	6	1
312A	1[e]	16.0	-	99	-	-	-	-	-	-	-	76	17	7	-
312B	4[f]	3.6	4	56	4	1	11	27	41	14	2	58	10	20	12
312C	5[g]	5.1	8	43	1	9	14	25	47	4	-	72	10	11	7
313	8	0.86	14	39	3	11	10	15	47	12	2	73	12	13	2
314	10	0.88	27	22	4	5	12	15	60	3	1	77	12	9	2
315	12[e]	0.43	14	26	6	1	17	26	50	-	-	76	12	8	4
315A	1[e]	0.61	6	82	-	-	17	17	66	-	-	69	14	11	6
315B	3[f]	0.72	26	27	5	1	13	15	58	4	4	80	11	6	3
315C	5[g]	0.52	35	20	-	39	16	21	24	-	-	71	18	10	1
316	11	0.50	25	30	3	10	27	19	37	2	2	76	9	5	10
317	10	0.45	23	22	4	7	19	24	43	2	1	88	10	2	-
318	9	0.18	17	24	5	7	11	27	48	2	-	84	11	3	2
320	12	0.22	12	26	4	14	21	24	34	3	-	70	16	11	3
327	11	0.84	21	20	2	3	14	16	62	2	1	78	9	9	4
328	15	0.48	19	19	6	4	12	23	52	2	1	80	14	4	2
329	25	0.06	16	20	2	5	26	26	33	8	-	78	13	5	4
330	11	0.05	9	38	7	8	11	32	35	3	4	83	10	5	2
331	25	0.05	15	36	8	10	9	40	32	-	1	77	17	4	2
334			9	13	4	1	28	13	47	6	1	79	15	3	3
335	15	1.12	22	8	2	2	6	18	61	5	6	74	18	5	3
336	20	0.97	18	17	-	5	10	11	61	13	-	81	14	5	-
337	22	0.90	22	13	3	2	19	27	44	2	3	69	21	8	2

Sample															
338	3	3	11	83	–	–	48	23	21	5	3	19	21	0.44	14
339	2	3	18	77	1	2	35	36	22	2	2	13	27	0.35	10
340	1	6	14	79	–	3	29	34	25	6	3	14	24	0.48	10
344	4	12	12	72	2	5	62	18	7	4	2	27	7	0.68	4
345	5	13	17	65	1	4	68	11	11	4	2	35	7	0.95	6
348	10	7	18	65	1	7	70	12	9	–	1	6	5	0.90	12
357	3	10	12	75	1	3	61	20	14	1	1	21	5	0.71	14
358	2	9	16	73	–	5	56	23	14	2	–	9	13	0.71	9
365	5	6	21	68	2	–	65	16	16	–	1	18	19	0.90	13
369	9	5	19	67	6	7	54	25	6	1	1	18	10	0.80	10
372	4	6	19	71	2	2	61	24	10	1	–	7	9	0.90	11
374	6	7	23	64	1	8	56	17	17	1	1	25	4	0.82	21
376	1	8	12	79	3	–	67	18	8	–	1	14	19	0.96	17
377	2	9	12	77	6	3	46	23	10	2	6	32	5	0.36	22
378	2	7	12	79	9	2	63	10	10	6	3	40	4	0.55	9
384	6	5	23	66	4	7	60	21	8	3	–	14	7	1.00	14
390	7	11	21	61	2	5	63	22	7	–	0	11	12	1.80	3
391	12	7	21	60	3	10	59	24	4	1	–	11	11	1.80	5
394	11	10	21	58	–	8	57	20	13	–	1	11	5	1.04	4
395	3	9	18	70	1	6	68	10	12	1	2	8	3	0.79	6
400	5	8	23	64	3	4	70	15	6	1	1	11	2	1.30	2
401	5	8	20	67	4	22	45	22	6	1	–	6	13	2.80	12
402	1	5	14	80	2	4	58	18	13	4	1	10	5	1.10	14
403	1	5	16	78	1	7	62	13	15	0	2	12	4	1.20	18
404	2	7	18	73	5	10	61	16	7	0	1	10	11	2.60	3
405	3	10	25	62	4	9	66	11	8	1	1	4	3	1.20	13
407	4	10	23	63	2	7	63	17	10	1	–	6	10	1.90	17
408	1	7	19	73	–	6	54	23	14	2	1	16	8	1.10	14
409	2	5	12	81	4	9	60	17	6	3	1	17	10	1.50	23
410	2	6	20	72	2	4	64	16	11	2	1	15	7	1.30	20
411	1	7	18	75	1	4	59	21	11	3	1	8	7	1.30	13
412	1	6	15	78	2	1	62	18	15	1	1	17	5	0.92	22
413	3	6	14	77	4	5	65	17	7	1	1	10	12	0.88	25
415	2	7	18	73	–	5	55	18	17	1	4	9	7	0.85	19
416	1	4	18	77	2	4	61	13	16	1	3	9	12	0.67	24
417	1	7	19	73	1	7	49	19	20	2	3	13	16	0.82	20
421	6	5	20	69	2	5	65	15	12	1	–	8	13	1.20	9
422	8	4	20	68	1	6	56	18	17	1	1	9	22	0.79	20

Table 2. - Continued

Sample no.	.062-.250 fraction[a] %	Heavy minerals in fraction %	Opaque heavy minerals Black %	Others %	Transparent heavy minerals (percent) Tourmaline	Zircon	Garnet	Epidote	Hornblende	Other amphiboles, pyroxenes	Others	Light Minerals (percent) Quartz	K-feldspar	Na-Ca feldspar	Others
431	6	1.50	4	5	-	1	7	8	82	2	-	67	10	21	2
601	11	0.82	22	21	8	-	12	25	50	3	2	78	9	9	4
602	8	0.46	24	25	5	6	14	28	30	-	17	83	10	4	3
603A	21	0.62	22	18	6	3	17	30	36	4	4	80	10	9	1
603B	14	0.28	23	16	5	3	14	28	43	3	4	83	10	4	3
603C	17	0.62	14	18	4	4	12	30	42	3	5	82	10	7	1
603D	19	0.68	18	25	3	5	12	34	38	4	4	79	11	9	1
603E	17	0.63	16	27	6	3	9	33	39	3	7	85	8	6	1
619	15	1.35	9	16	2	3	22	18	52	2	1	70	15	12	3
621	17	1.20	10	21	4	1	18	16	59	-	2	71	16	11	2
622	13[h]	0.47	19	20	5	6	8	35	44	-	2	82	12	5	1
674	16[h]	0.77	8	29	4	9	19	18	50	-	-	82	11	4	3
675	13[h]	0.15	17	27	4	3	17	21	52	3	-	82	8	6	4
676	16[h]	0.78	15	19	1	4	20	20	51	4	-	80	12	4	4
677	12	0.61	13	24	4	3	25	18	48	1	1	77	13	7	3
678	10	0.53	14	26	9	6	21	15	45	4	-	82	10	4	4
679	9	0.55	14	33	5	7	18	33	35	2	-	80	10	7	3
680	7	0.41	15	28	7	3	18	24	42	3	3	84	8	5	3
681	6	1.24	7	33	7	8	12	31	37	3	2	85	9	4	2
682	6	0.43	8	31	3	8	15	36	37	-	1	83	11	5	1
687	15	0.30	1	47	9	1	12	10	62	3	3	71	12	13	4
688	15	0.28	5	26	4	7	10	17	58	3	1	77	11	9	3
689	13	0.39	11	25	7	2	12	16	54	3	6	75	13	9	3
690	14	0.85	10	28	3	2	17	30	46	-	2	72	12	12	4
691	8	0.31	9	26	3	2	8	37	48	1	1	79	9	8	4
705	24	0.66	4	11	1	1	13	19	61	3	2	76	18	4	2
706	22	1.00	11	15	3	1	13	21	58	3	1	82	14	3	1
707	29	1.07	7	11	3	-	9	24	64	-	-	73	18	5	4
708	27	0.64	10	16	3	1	14	28	45	6	3	76	15	6	3
709	27	0.49	13	21	5	2	14	23	54	2	-	71	20	5	4

No.															
710	2	4	18	76	-	5	57	19	14	1	4	14	20	0.43	25
711	1	4	9	86	1	1	49	21	17	8	3	18	23	0.53	23
712	2	3	11	84	-	2	47	25	12	9	5	17	21	0.54	24
713	2	12	19	67	1	9	50	24	11	1	4	6	12	0.97	14
714	3	8	17	72	1	8	58	21	10	1	1	16	12	0.97	13
715	-	5	18	77	-	1	62	21	14	1	1	17	15	0.58	15
716	9	3	22	66	2	8	56	19	13	-	2	15	8		32
717	4	7	17	72	1	8	61	12	16	1	1	14	15	1.30	28
718	3	7	14	76	3	6	63	15	10	1	2	10	15	1.10	17
726	3	7	19	71	-	4	60	20	12	1	3	19	5	0.72	16
727	3	4	16	77	-	9	50	22	18	1	-	12	7	0.74	18
728	1	2	16	81	-	2	54	27	13	4	-	20	10	0.88	20
750	3	11	13	73	4	11	47	16	17	2	3	20	1	0.50	15
751	2	9	14	75	2	3	48	23	22	1	1	19	3	0.34	23
752	4	6	14	76	-	3	44	30	18	3	2	23	4	0.16	26
753	4	7	14	75	2	1	47	32	13	3	2	15	7	0.25	22
754	2	5	12	81	2	1	49	26	19	1	2	14	9	0.10	
762	6	7	18	69	6	2	56	18	14	2	2	15	5	0.69	15
763	8	6	18	68	2	2	60	15	16	2	3	17	4	0.54	19
764	6	9	17	68	3	3	68	15	10	1	-	16	11	0.42	27
765	7	7	20	66	2	1	64	17	15	-	1	18	6	0.54	21
766	7	4	16	73	1	-	66	18	13	1	1	12	12	0.62	23
767	8	5	19	68	-	1	63	15	15	3	3	19	6	0.29	21
768	9	5	17	69	-	4	47	35	11	2	1	23	4	0.63	24
769	7	4	18	71	2	3	45	27	20	2	1	14	4	0.31	23
770	3	7	14	76	2	-	38	31	24	2	3	13	7	0.23	30
771	5	5	14	76	-	-	59	23	14	2	2	16	6	0.35	27
772	3	6	20	71	4	2	60	23	7	3	1	17	6	0.37	17
773	3	6	18	73	2	-	64	19	13	1	1	12	10	0.96	15
774	6	4	17	73	7	1	62	20	11	1	5	12	7	0.21	17
775	3	5	15	77	-	-	57	28	9	4	2	12	8	0.24	27
779	9	6	11	74	4	3	56	12	18	4	3	29	10	1.24	10
780	7	5	10	78	2	3	70	9	9	3	2	21	7	0.21	12
781	3	5	12	80	2	2	56	16	16	5	1	27	8	0.96	15
782	8	6	14	72	7	-	48	19	16	5	5	26	9	0.54	12

Table 2. - Continued

Sample no.	.062-.250 fraction %	Heavy minerals in fraction %	Opaque heavy minerals		Transparent heavy minerals (percent)							Light minerals (percent)			
			Black %	Others %	Tourmaline	Zircon	Garnet	Epidote	Hornblende	Other amphiboles, pyroxenes	Others	Quartz	K-feldspar	Na-Ca feldspar	Others
783	14	1.00	11	23	1	3	18	18	58	-	2	77	13	7	3
784	16	0.55	16	22	1	4	18	11	46	1	19	79	12	7	2
785	17	0.57	14	21	6	5	17	28	43	-	1	78	13	7	2
786	18	0.63	6	32	-	2	21	15	58	1	3	82	15	3	-
787	22	0.62	12	26	3	6	23	25	39	-	4	83	10	5	2
788	25	0.17	6	26	1	3	14	25	54	-	3	86	9	3	2
789	11	0.93	12	32	7	3	17	26	46	-	1	82	10	5	3
791	18	0.50	20	22	6	5	18	16	52	-	3	82	10	5	3
792	19	0.44	16	21	3	5	13	24	53	-	2	84	10	4	2

a Material coarser than 2 mm in diameter was excluded from the sample before analysis.

b Percent in 0.062 - 0.125 mm size fraction, from Brophy (1959).

c Percent in 0.125 - 0.250 mm size fraction, from Brophy (1959).

d Percent in 0.250 - 0.50 mm size fraction, from Brophy (1959).

e Percent in 0.50 - 0.71 mm size fraction.

f Percent in 0.125 - 0.250 mm size fraction.

g Percent in 0.031 - 0.062 mm size fraction.

h Percent in 0.044 - 0.250 mm size fraction.

Table 3. - Clay Mineral and Carbonate X-Ray Analyses

Sample no.	X-ray intensities (counts per sec.) Calcite	Dolomite	Montmorillonite*	Expandable vermiculite	Mixed-lattice clay minerals	Vermiculite and vermiculite-chlorite	Chlorite	Illite	Kaolinite
1	22	70	+				+	++	?
2	-	-	+				+	++	?
3	-	-	+			+		++	+
13	-	-		+				++	+
16	-	-		+				++	?
24	-	-		+				++	
26	18	42	+		+	+		++	+
57	-	-	+++					+	++
60	-	-	+++					?	++
61	-	-	+++					+	++
94	16	75	+		+	?		++	+
97	20	80	+			++		++	+
98	-	-		+		?		++	+
113	23	42	?		+	+		++	+
114	-	-				++		++	+
119	45	80	+				+	++	+
120	22	55	+				+	++	+
123	35	55	++				?	++	+
124	-	-	++				?	++	+
125	25	38	+			+		++	+
126	16	80					+	++	?
131	35	85					+	++	+
132	-	-	+++			?		+	++
138	55	100	?				+	++	+
139	45	75			+	+		++	?
145	44	95					+	++	?
146	52	88					+	++	?
148	26	75					+	++	?
170	?	55				+		++	
171	13	30					+	++	?
172	25	80			+	+		++	
173	20	60	?				+	++	+
180	30	45					+	+++	++
181	26	35					+	+++	++
182	22	30					+	+++	++
183	45	25			+	+		+++	++
184	40	20			+	+		+++	++
185	10	30			+	+		+++	++
186	-	-			+	++		+++	++
188	-	-			+	+++		++	++
189	-	-	++					+	+
190	-	-	++					+	+

Table 3. - Continued

Sample no.	X-ray intensities (counts per sec.) Calcite	Dolomite	Montmorillonite*	Expandable vermiculite	Mixed-lattice clay minerals	Vermiculite and vermiculite-chlorite	Chlorite	Illite	Kaolinite
191	-	-	+					+	+
192	-	-	+					+	+
195	35	135	+				+	+++	+
196	55	95	+				+	+++	++
197	40	105	+		+	+		+++	++
198	20	120			+	+		+++	+
199	-	155			+	+		+++	+
200	-	-			+	+		+++	+
201	-	-	+		+	+		+	+
202	-	-	+++			?		+	+
203	-	-	++			?		+	+
204	-	-	+			+		?	+
205	-	-	+++			+		?	++
206	-	-	+++			+		?	++
207	-	-	+++			+		?	+
208	-	-	+++			+		?	++
209	-	-	+++			+		?	+
291	-	-			+	+		+++	++
292	-	-	+++	++				+	++
293	-	-		+++				+	+
294	-	-	+++					+	+
312	18	85					+	++	?
313	-	40			+	+		+++	+
314	-	-			+	++		++	+
315	-	-		++				++	+
316	-	-		++				++	+
317	-	-		++				++	+
318	-	-	++					+	+
320	-	-	+++					+	+
327	-	-			+	+		+++	++
328	-	-			+	++		++	++
329	-	-		++				++	+
330	-	-	+++	++				+	++
331	-	-	+++	++				+	++
334	-	-		++				+	+
335	45	100	+			+		+++	+
336	-	-	+		+	+		+++	+
337	-	-		++				+++	+
338	-	-		++				++	+
339	-	-		++				++	+
340	-	-		+				++	+
344	15	45					+	+++	
345	-	-				++		+++	
357	17	55			+	++		+++	
358	-	-		+				++	?
365	55	70	+			+		++	+
369	20	60			+	++		+++	+
372	50	105			+	+		++	

Table 3. - Continued

Sample no.	X-ray intensities (counts per sec.) Calcite	Dolomite	Montmorillonite*	Expandable vermiculite	Mixed-lattice clay minerals	Vermiculite and vermiculite-chlorite	Chlorite	Illite	Kaolinite
374	25	85					+	++	?
376	25	60				+		++	+
377	-	-	?		+	+++		++	+
378	-	-	+		+	++		++	+
384	45	105			+	++		++	+
390	15	75					+	+++	
391	40	75				++		+++	+
394	45	85				+		+++	?
395	-	-			+	++		+++	+
400	40	80			+	+		+++	?
401	-	240			+	+		++	
402	-	195	?		+	+		++	?
403	35	140			+	+		++	?
404	40	100					+	++	?
405	-	195	+			+		++	
407	15	215	+			+		++	
408	35	140	++			+		++	+
409	?	110	++			+		++	+
410	-	-	++			+		++	?
411	15	170	+			+		++	
412	-	90	+			+		++	
413	-	-	++			+		++	
415	-	205	+			+		++	
416	-	-	+			+		++	
417	-	-	+			+		++	
421	-	245	+			+		++	
422	-	-	+			+		++	
431	65	165	+			+		++	?
601	30	-	+++			+		++	++
602	15	-	+++			?		++	++
603A	-	-	++					++	+
603B	-	-	++					++	+
603C	-	-		++				++	+
603D	-	-	++					++	+
603E	-	-	++					++	+
619	-	40		+	+	+		++	+
621	-	10		+	+	+		++	+
622	-	-		++	+	+		++	+
674	-	-			+		+	+++	++
675	-	-			+		+	+++	++
676	-	-			+		+	+++	++
677	-	-		+	+			+++	++
678	-	-		+				++	+
679	-	-		+				++	+
680	-	-		+				++	+
681	-	-		+				+	+
682	-	-		+				+	+
687	11	65					+	++	?

Table 3. - Continued

Sample no.	X-ray intensities (counts per sec.) Calcite	Dolomite	Montmorillonite*	Expandable vermiculite	Mixed-lattice clay minerals	Vermiculite and vermiculite-chlorite	Chlorite	Illite	Kaolinite
688	-	-					+	++	?
689	-	-		+				++	+
690	-	-		+				++	?
691	-	-	++					+	+
705	18	140	+			+		++	
706	-	25	+	+		?		++	
707	-	-		+		?		++	
708	-	-		+		?		++	
709	-	-				+		++	
710	-	-				+		++	
711	-	-				+		++	
712	-	-	?			+		++	
713	13	195	++				+	++	
714	-	90	++				+	++	
715	-	75	++				+	++	
716	-	-	++			?		++	
717	-	-	++			?		++	
718	-	-	++					++	?
726	25	65					+	+++	+
727	-	60				+		+++	+
728	-	-		+	+	+		+++	+
750	25	75			+	++		++	+
751	-	-			+	+++		++	
752	-	-	+++			+		+	+
753	-	-	+++			+		+	+
754	-	-	+++			+		+	+
762	25	115				+		++	
763	-	35	+			++		++	
764	-	-	+			++		++	
765	-	-	+			++		++	
766	-	-	+			++		++	
767	-	-	+			+++		+++	+
768	-	-	+			+++		+++	+
769	-	-	+++			+		+	+
770	-	-	+++			+		+	+
771	-	-	+++			+		+	+
772	-	-	+++			+		+	+
773	-	-	+++			+		+	+
774	-	-	+++			+		+	+
775	-	-	+++			+		+	+
779	12	30				+		++	+
780	-	25			+	+		++	+
781	-	-			+	+		+++	+
782	-	-			+	+		+++	+
783	-	-	++	++				+++	+
784	-	-	+++					+	+
785	-	-	+++					+	+
786	-	-	+++					+	+

Table 3. - Continued

Sam-ple no.	X-ray intensities (counts per sec.) Calcite	Dolomite	Montmoril-lonite*	Expand-able vermicu-lite	Mixed-lattice clay minerals	Vermiculite and vermiculite-chlorite	Chlor-ite	Illite	Kaolin-ite
787	-	-	+++					+	+
788	-	-	+++					+	+
789	-	-	+++					+	+
791	-	-			+	+		+	+
792	-	-		+	+			?	+

* +++ designates a strong indication of the mineral in the x-ray pattern;
++ designates a moderate indication; + designates a weak indication;
? designates doubtful identification.

Table 4. - Average Mineral Content of Winnebago and Illinoian Tills
by Zones of Weathering Profile

Heavy Minerals

Profile zone	K-feld-spar	Na-Ca feld-spar	No. of samples	Tour-maline & zircon	Garnet	Epidote	Horn-blende	Total ferro-magnesian minerals	No. of samples
				Illinoian Till					
G	13	5	22	7	16	26	48	49	22
A	11	5	9	12	14	30	39	41	5
B	12	6	31	10	18	25	43	46	16
BG	14	7	6	5	18	27	46	49	6
CL	14	7	19	6	14	19	57	60	16
CC	12	8	25	6	14	17	52	57	24
Unoxi-dized	11	10	12	7	23	21	51	57	2
				Winnebago Till					
G	18	8	4	11	18	28	40	44	4
A	12	5	2	8	11	20	52	56	2
B	16	6	7	5	15	19	55	60	8
CL	18	5	2	3	13	19	60	64	3
CC	17	6	6	3	12	18	62	66	8
Unoxi-dized	19	8	2	4	12	22	56	62	2

Table 5. - Content of Coarse and Fine Clay
in the Hipple School and Rochester Sections

Sample no.	Zone	Percent total clay	Percent <0.5 micron	Percent <2,>0.5 micron
762	CC	14.8	10.0	4.8
763	CC	15.5	11.3	4.2
764	CL	11.2	10.8	0.4
765	CL	20.2	16.3	3.9
766	CL	18.0	15.5	2.5
767	CL	29.0	21.0	8.0
768	BG	25.6	19.1	6.5
769	G	34.0	27.6	6.4
770	G	34.7	28.4	6.3
771	G	37.2	30.8	6.4
772	G	37.4	31.0	6.4
773	G	39.7	33.8	5.9
774	G	40.3	34.7	5.6
775	G	31.4	26.1	5.3
777		11.4	7.5	3.9
778		26.1	16.2	9.9
779	CC	26.6	15.3	11.3
780	CC	28.6	17.6	11.0
781	CL	33.3	22.9	10.4
782	CL	31.8	20.5	11.3
783	CL	30.0	20.9	9.1
784	BG	29.7	22.6	7.1
785	G	37.0	34.8	2.2
786	G	36.6	28.8	7.8
787	G	38.8	32.9	5.9
788	G	42.4	36.9	5.5
789	G	41.2	36.9	4.3
791	B	32.2	25.9	6.3
792	B	39.5	34.2	5.3

REFERENCES

Allen, Victor T., 1959, Gumbotil and interglacial clays: Geol. Soc. Amer. Bull., v. 70, p. 1483-1486.

Brophy, J. A., 1959, Heavy mineral ratios of Sangamon weathering profiles in Illinois: Illinois Geol. Survey Circ. 273, p. 1-22.

Droste, John, and Thorin, J. C., 1958, Alteration of clay minerals in Illinoian till by weathering: Geol. Soc. Amer. Bull., v. 69, p. 61-68.

Frye, J. C., and Willman, H B., 1960, Classification of the Wisconsinan Stage in the Lake Michigan glacial lobe: Illinois Geol. Survey Circ. 285, 16 p.

Frye, J. C., Shaffer, P. R., Willman, H B., and Ekblaw, G. E., 1960, Accretion-gley and the gumbotil dilemma: Amer. Jour. Sci., v. 258, p. 185-190.

Goldich, S. S., 1938, A study of rock-weathering: Jour. Geology, v. 46, p. 17-58.

Gravenor, C. P., 1954, Mineralogical and size analysis of weathering zones on Illinoian till in Indiana: Amer. Jour. Sci., v. 252, p. 159-171.

Kay, G. F., 1916a, Gumbotil, a new name in Pleistocene geology: Science, n. ser., v. 44, p. 637-638.

Kay, G. F., 1916b, Some features of the Kansan drift in southern Iowa (abst.): Geol. Soc. Amer. Bull., v. 27, p. 115-116.

Kay, G. F., and Apfel, E. T., 1929, The pre-Illinoian Pleistocene geology of Iowa: Iowa Geol. Survey, v. 34, p. 1-262.

Kay, G. F., and Pearce, J. N., 1920, The origin of gumbotil: Jour. Geology, v. 28, no. 2, p. 89-125.

Krusekopf, H. H., 1948, Gumbotil — its formation and relation to overlying soils with clay pan subsoils: Soil Sci. Soc. Amer. Proc., v. 12, p. 413-414.

Leighton, M. M., and MacClintock, Paul, 1930, Weathered zones of the drift sheets of Illinois: Jour. Geology, v. 38, no. 1, p. 28-53.

Ruhe, R. V., 1956, Geomorphic surfaces and the nature of soils: Soil Science, v. 82, no. 6, p. 441-455.

Simonson, R. W., 1954, Identification and interpretation of buried soils: Amer. Jour. Sci., v. 252, p. 705-732.

U. S. Department of Agriculture, 1951, Soil Survey Manual: U. S. Dept. Agr. Handbook No. 18, 503 p.

Willman, H. B., 1942, Feldspar in Illinois sands: Illinois Geol. Survey Rept. Inv. 79, 87 p.

ILLINOIS
Land of Lincoln

114