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MINERAL ZONATION OF WOODFORDIAN LOESSES OF ILLINOIS

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MINERAL ZONATION OF WOODFORDIAN LOESSES OF ILLINOIS

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

ABSTRACT

The Woodfordian loesses of central and western Illinois are zoned on the basis of their clay-mineral composition. These zones are related to the composition of outwash in the major source valleys. In the Illinois Valley, three zones are distinguished by successively higher amounts of illite. In the Mississippi Valley of western Illinois, low amounts of illite and high amounts of montmorillonite occur in the bottom and top zones with a middle zone characterized by higher amounts of illite. In the north-central part of the state, a still higher zone, characterized by high amounts of montmorillonite, overlies the other zones. The relative degree of mineral alteration in the modern soils is evaluated by the development of a "heterogeneous swelling index." The data suggest that surface soils in west-central Illinois loess have formed during about 12,000 ± 1000 radiocarbon years, and those of the central Illinois Valley region have formed during about 14,000 ± 1000 radiocarbon years.

INTRODUCTION

Three-fourths of the surface of Illinois is underlain by loess that commonly ranges from a few feet to more than 50 feet in thickness. It rests on both glacially derived deposits and on bedrock, and because of its position just below the surface, it is important in construction projects, as fill material, as the parent material for much of the state's soil, and locally for such uses as ceramic raw material. The Illinois State Geological Survey has studied the stratigraphy and mineral composition of the surficial loesses (Frye, Glass, and Willman, 1962; Frye and Willman, 1963; Glass, Frye, and Willman, 1964), and this report gives the results of studies of the mineralogical zonation of the youngest, or uppermost, loess units.

Because the zonation of the Woodfordian loess is limited to those areas where it is quite thick, this study was made in the belts of thick loess adjacent to the Illinois and Mississippi Valleys (fig. 1). The objective has been to define not only the recognizable zones in the loess, but also to relate the mineral composition and stratigraphy of these zones to that of Woodfordian tills that resulted from the repeated glacial advances and retreats (Frye, Willman, and Black, 1965).

The mineral compositions of the Woodfordian tills of northeastern and central Illinois contrast with the compositions of the Illinoian and Kansan tills of the state (Willman, Glass, and Frye, 1963; 1966), and within the Woodfordian tills there are two clay-mineral compositional groups. Within the Illinois Valley region, the tills from the Shelbyville, at the base, upwards through and including the Bloomington are characterized by higher percentages of expandable clay minerals and lower percentages of illite than are the tills overlying the Bloomington. As the outwash was the primary source of loess in the Illinois Valley region, this compositional change should be, and is, detected in the loess deposits.

With the exception of this one change in the clay-mineral composition of the loess, the other changes are attributed to modifications in major drainage lines caused by glacial diversions (Glass, Frye, and Willman, 1964). Thus, it is necessary to briefly review the drainage history of central and western Illinois as a basis for understanding the mineral zonation of the Woodfordian loesses.

The major stream during Farmdalian time (Frye, Willman, and Black, 1965) was the Ancient Mississippi River that occupied the position of the present Mississippi in northwestern Illinois (fig. 1). From there, it flowed east-southeast from the vicinity of Cordova and Erie, by way of the now buried Princeton Valley, to the area of the Big Bend of the Illinois Valley near Hennepin. From the vicinity of Hennepin, it flowed southward along the Illinois Valley to the Mississippi Valley. Thus, the Ancient Mississippi Valley was in a position to receive and carry outwash from the advancing early Woodfordian glaciers from as far north as eastern Minnesota and northwestern Wisconsin. In north-central Illinois it was joined by outwash carrying streams from the Lake Michigan lobe. As a result, the composition of the loess deposited during earliest Woodfordian time along the

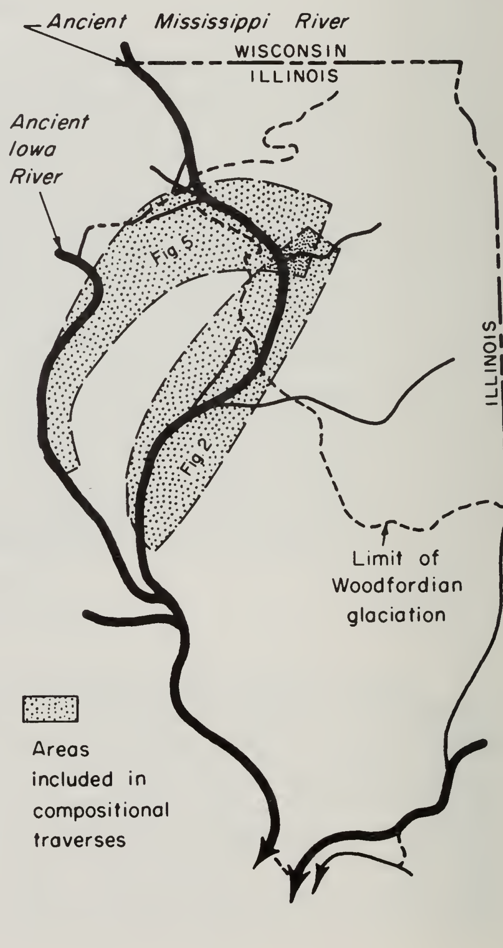


Figure 1 - Location map.

Illinois Valley is a blend of sediments from a broad region to the north, northwest, and northeast.

In contrast, that part of the present Mississippi Valley below Rock Island County received outwash only from the earliest Woodfordian glaciers advancing into the Des Moines lobe of north-central Iowa. This valley was part of a drainage system, called the Ancient Iowa, that originated in north-central Iowa and south-central Minnesota and occupied the present valley of the Mississippi from near Muscatine southward to the St. Louis area.

This regional drainage pattern persisted until the glacier advancing toward the west from the Lake Michigan lobe blocked the Princeton Valley and diverted the Ancient Mississippi River across the high bedrock in the Moline-Rock Island area (Shaffer, 1954; MacClintock and Willman, 1959). After this diversion, the Mississippi Valley above St. Louis was receiving outwash from the headwaters of the Ancient Mississippi Valley, from the region of north-central Iowa, and from the Lake Michigan lobe through the reversed Princeton Valley.

After this blockage and diversion, determined to be approximately 21,000 radiocarbon years B.P. (Glass, Frye, and Willman, 1964), the lower Illinois Valley portion of the Ancient Mississippi Valley was deprived of all outwash except that originating from the Lake Michigan lobe itself.

After the Woodfordian glaciers retreated from the position of the Bloomington Moraine, which extended across the Princeton Valley, northeastern outwash no longer was fed into the Mississippi Valley. By then, the present Mississippi River was established, and it continued to receive outwash from the Des Moines lobe glaciers of north-central Iowa, as well as from northeastern Minnesota and northwestern Wisconsin.

The Illinois Valley, on the other hand, lost its source of outwash by late Woodfordian time because of the formation of Lake Illinois (Willman and Payne, 1942), and, subsequently, Lake Chicago. These lakes, through which flowed the meltwater from the glaciers, served as a trap for outwash and effectively eliminated the Illinois Valley as a source of loess. In contrast, outwash continued to be carried down the Mississippi Valley to serve as a loess source, perhaps to as late as Valderan time.

Each of these changes in drainage pattern, as well as the change in composition of the Lake Michigan lobe tills, should be reflected in the composition of the loess deposits along the major valleys. The analytical data presented here show the relation of the recognizable compositional zones in the loess to this glacial history.

The Woodfordian loesses of Illinois are classed in three stratigraphic units (Frye and Willman, 1960). Beyond the limits of Woodfordian glacial advance, all loess of this age is included within the Peoria Loess. Within the region of glacial tills of Woodfordian age, the loess that occurs stratigraphically above Farmdale Silt and is overlain by glacial till is called the Morton Loess, and the loess that occurs above these tills is called the Richland Loess. The mineralogically distinctive zones that will be described are subdivisions of these stratigraphic units.

The clay minerals in loess may be considered as complex assemblages of four primary clay minerals—montmorillonite, illite, chlorite, and kaolinite—and the secondary clay mineral, vermiculite, formed as an alteration product of both illite and chlorite. The vermiculite is most difficult to evaluate or quantify, as it occurs in all stages of alteration through complex mixed-lattice clay minerals to material that expands with ethylene glycol treatment and is indistinguishable from montmorillonite. It should be noted that in this report, the terms montmorillonite and vermiculite refer to specific clay minerals, whereas the term expandable clay minerals refers to mixtures of montmorillonite and vermiculite. The clay minerals in loess reflect the primary source area materials, as well as their alteration products formed at the source, during transport, and by weathering after deposition.

It has been shown (Willman, Glass, and Frye, 1963) that tills deposited by glaciers entering Illinois from the northeast have illite as the dominant clay mineral with lesser amounts of chlorite-vermiculite, whereas tills deposited by glaciers entering Illinois from the northwest have montmorillonite as the dominant clay mineral with minor amounts of kaolinite and illite, with chlorite usually absent. The mineralogy of the loess, therefore, is related to the varying contributions from the glaciers in the source areas that furnished outwash to the major valleys, and secondarily to any "blow-over"effects from areas to the west by the prevailing winds.

The various factors that contribute to clay-mineral composition of the loess create problems in the tabulation of data, as some zone boundaries are transitional whereas others are extremely sharp. Within the individual zones, composition may be essentially homogeneous or completely gradational. The compositions are here expressed and tabulated as three values, which respectively indicate the percentages of expandable clay minerals (montmorillonite and vermiculite), illite, and kaolinite plus chlorite in the less-than-two micron fraction. In order to present the most significant data to supplement the principles discussed, tabulations are made showing the compositions with the maximum or minimum amount of illite for all zones. The nature of the zonal contact, whether sharp or transitional, is also indicated. Also shown in the tables is the diffraction intensity ratio (D.I. ratio). This ratio is a numerical value that shows the relationship in the loess of illite to chlorite plus kaolinite (Frye, Glass, and Willman, 1962, p. 7).

The mineralogical data used in this study are given at the end of the report in table 1. The location and the description of the stratigraphic position and lithology are given in the measured geologic sections included at the end of this report for all previously unpublished sections. The descriptive sections that have been published previously are indicated by reference to the report in which each was published.

ZONATION IN THE ILLINOIS VALLEY

The traverse along the Illinois Valley (fig. 1) extends from Greene County at the south to LaSalle County at the north and is based on analytical data from 20 measured sections. The traverse crosses the boundary of the area glaciated during Woodfordian time. Nine of the sections used are beyond this glacial limit and, therefore, deal with the Peoria Loess, whereas 11 occur within the area of Woodfordian tills and are concerned with the Morton and Richland Loesses. Physical and mineralogical continuity extends from the Peoria into the Morton and the Richland, which makes it possible to establish the physical relations of the loess zones to the various till sheets.

The relations of the recognizable compositional zones within the loess to the tills along this traverse are shown diagramatically in figure 2. Zone I at the base is characterized by relatively high montmorillonite and low illite (fig. 3; tables 2 and 3), and its source was the outwash carried by the Ancient Mississippi River during the period of advance of the Woodfordian glaciers. These glaciers, advancing from the Keewatin center, crossed the montmorillonite-rich Cretaceous rocks, and thus the valley primarily received montmorillonite from the northwest. In north-central Illinois, outwash rich in illite, chlorite, and vermiculite, derived from the Paleozoic rocks to the north and northeast, was mixed with the northwestern outwash. The outwash was further diluted with additional high-illite sediments, also from Paleozoic rocks, southward along the valley.

The termination of the deposition of Zone I and the initiation of the deposition of Zone II in the Illinois Valley was relatively sudden because it was produced by the diversion of the northwestern outwash by the Woodfordian glacier advancing from the northeast. The sediment source for Zone II was the outwash from early Woodfordian glaciers of the Lake Michigan lobe. Deprived of the dominantly montmorillonite source from the northwest, Zone II is characterized by a decrease in expandable clay minerals and an increase in the amount of illite in contrast to Zone I below. Zone II contains some montmorillonite from the west because the eastern feather edge of the Mississippi Valley loess extended to the Illinois Valley (figs. 3 and 4; table 3).

This sharp change in composition occurs in the Morton Loess below the Shelbyville till (Glass, Frye, and Willman, 1964). The compositional change takes place in a few inches vertically, although it is not detectable in the field by physical appearance. The data presented here permit the southward tracing of this compositional change within the Peoria Loess more than 100 miles beyond the Shelbyville Moraine. Southward from the Shelbyville Moraine, dilutions by eolian trans-

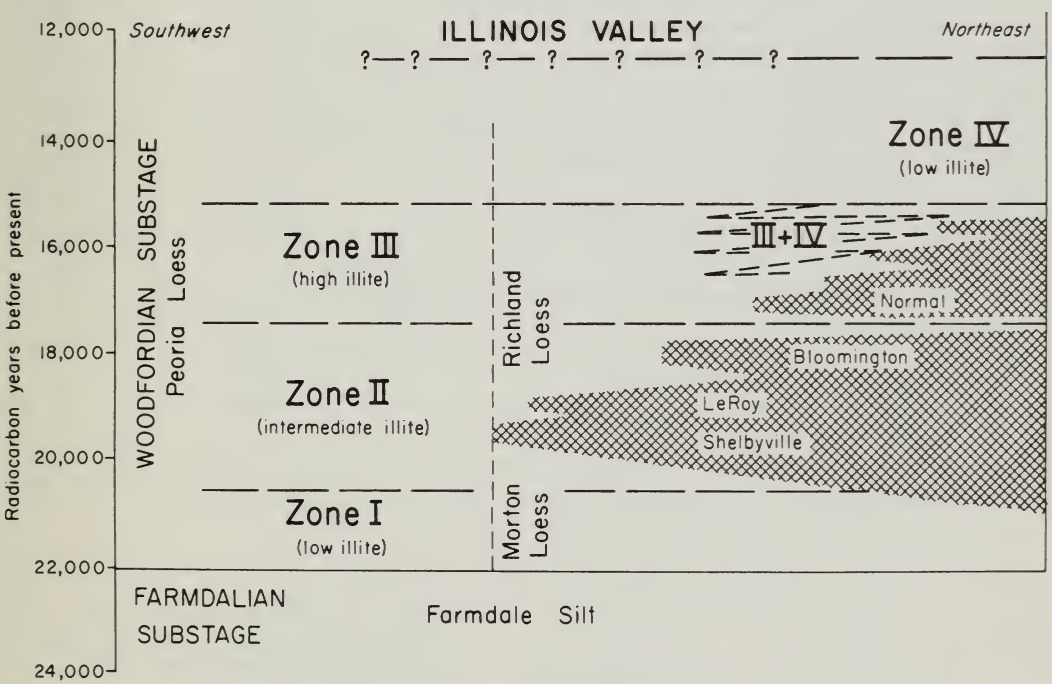


Figure 2 - Generalized diagram showing relation of compositional zones along Illinois Valley.

port from the west, by additional outwash from the northeast, and by mixing during outwash transport serve to blur the boundary of the two zones and they become transitional in the lower Illinois Valley.

Zone II is present not only within the upper part of the Morton Loess and the lower part of the Richland Loess (fig. 4) but is also differentiated within the Peoria Loess southward along the Illinois Valley (fig. 3; tables 2 and 3).

As the contact of Zones I and II indicates the point in time when the Ancient Mississippi was permanently blocked, its dating is quite significant. On the basis of radiocarbon data then available, Glass, Frye, and Willman (1964) proposed a date of 21,000 ± 500 radiocarbon years B.P. It now seems reasonable to suggest a narrower range of 20,500 to 21,000 radiocarbon years B.P.

Zone III, relative to Zone II, is characterized by an increase in abundance of illite and a decrease in expandable clay minerals (table 3). The correlation of this sharply defined zone boundary, recognizable throughout the lower and middle Illinois Valley, with the glacial sequence has been more difficult than for the lower boundary of Zone II because it is not related to a major disruption of drainage and attendant change in source. This problem of correlation was attacked first by clay-mineral analyses of Richland Loess resting on progressively younger tills in order to find the youngest till on which Zone II could be recognized, and second by analyses of the tills from the Lake Michigan lobe in search of changes that might be reflected in the composition of the derived loess. Both approaches proved successful and complemented one another.

On the earlier Woodfordian tills, Shelbyville, LeRoy, Bloomington, and Metamora, loess of Zone II was found at the base overlain by loess of Zone III. However, in Richland Loess resting

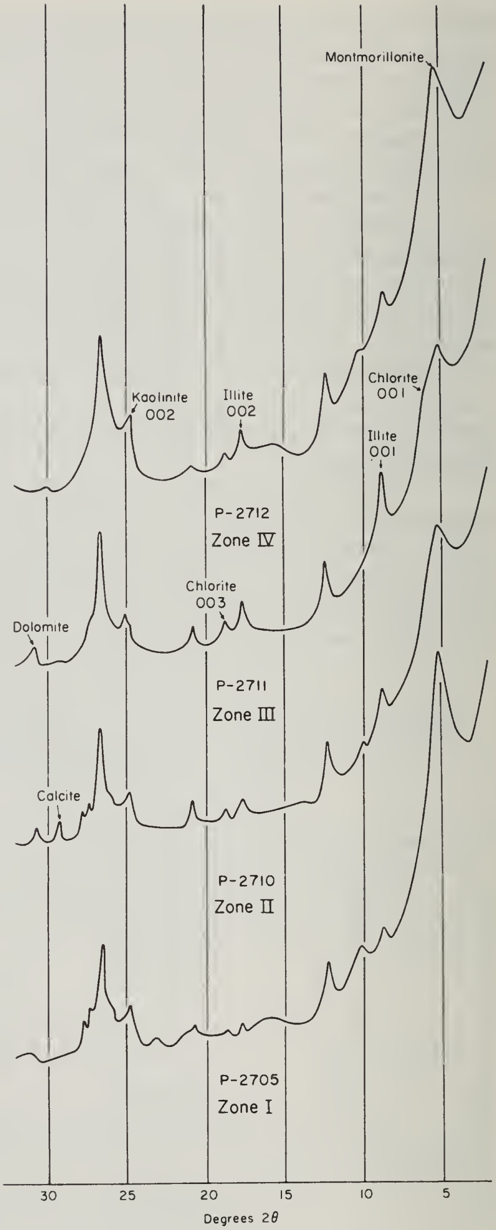


Figure 3 - Typical X-ray diffraction curves of Peoria Loess from the Pekin South section showing the compositional zones of the Illinois Valley.

TABLE 2 - SELECTED ANALYSES OF
PEORIA LOESS ALONG ILLINOIS VALLEY TRAVERSE

	Zone I					Zone II					Zone III					Zone IV			
Section	D. I. ratio	Expandable clay minerals (%)	Illite (lowest value) (%)	Kaolinite and chlorite (%)	Zone contact relations*	D. I. ratio	Expandable clay minerals (%)	Illite (highest value) (%)	Kaolinite and chlorite (%)	Zone contact relations*	D. I. ratio	Expandable clay minerals (%)	Illite (highest value) (%)	Kaolinite and chlorite (%)	Zone contact relations*	D. I. ratio	Expandable clay minerals (%)	Illite (lowest value) (%)	Kaolinite and chlorite (%)
Pekin South	0.7	87	7	6	G	1.7	61	28	11	S	3.4	43	47	10	G	1.5	62	27	11
Sister Creek	1.0	68	21	11	G	1.4	54	31	15	S	3.3	26	61	13	G	2.1	64	27	9
Sepo	0.9	74	15	11	G	1.5	63	26	11	S	2.6	42	45	13	G	1.8	64	25	11
Jules	0.6	66	16	18	G	1.5	66	24	10	S	2.3	43	45	12	G	1.5	68	22	10
Frederick South	0.6	69	15	16	G	1.0	66	21	13	S	2.1	54	37	9					
Rushville (0.4W)	0.7	71	15	14	G	1.6	65	25	10	S	2.0	55	34	11	G	2.2	68	25	7
Perry East	0.8	75	13	12	G	1.8	71	21	8	S	2.3	60	31	9					
Hillview						1.0	55	27	18	S	1.6	32	48	20					
Eldred						1.0	61	24	15	G	2.3	56	33	11					

* G=gradational; S= sharp

TABLE 3 - SELECTED ANALYSES OF RICHLAND AND MORTON LOESSES ALONG ILLINOIS VALLEY TRAVERSE

Section	Zone I					Zone II					Zone III					Zone IV			
	D. I. ratio	Expandable clay minerals (%)	Illite (%)	Kaolinite and chlorite (%)	Zone contact relations*	D. I. ratio	Expandable clay minerals (%)	Illite (highest value) (%)	Kaolinite and chlorite (%)	Zone contact relations*	D. I. ratio	Expandable clay minerals (%)	Illite (highest value) (%)	Kaolinite and chlorite (%)	Zone contact relations*	D. I. ratio	Expandable clay minerals (%)	Illite (lowest value) (%)	Kaolinite and chlorite (%)
RICHLAND LOESS																			
Bradford East											1.8	58	31	11	G	1.4	64	24	12
Granville											2.2	51	38	11	G	1.3	67	24	9
Mt. Palatine											1.6	59	29	12	G	1.1	68	20	12
Varna											2.3	53	36	11	G	1.1	79	13	8
Partridge Creek						1.5	63	27	10	S	3.2	43	47	10	G	1.3	78	14	8
10-mile School						1.6	66	24	10	S	2.8	46	44	10	G	2.1	66	26	8
Farm Creek						1.9	63	27	10	S	2.2	50	39	11	G	1.6	66	23	11
Marquette Heights						1.5	64	25	11	S	2.2	43	44	13	G	2.0	66	25	9
Studyvin School											3.0	43	46	11	G	1.6	61	28	11
MORTON LOESS†																			
Richland Creek	0.9	62	21	17	S	1.1	49	32	19										
Farm Creek	0.6	66	17	17	S	1.1	50	29	21										
Danvers	0.8	50	27	23	S	1.2	31	42	27										

*G=gradational; S=sharp
†Samples immediately above and below zone boundary

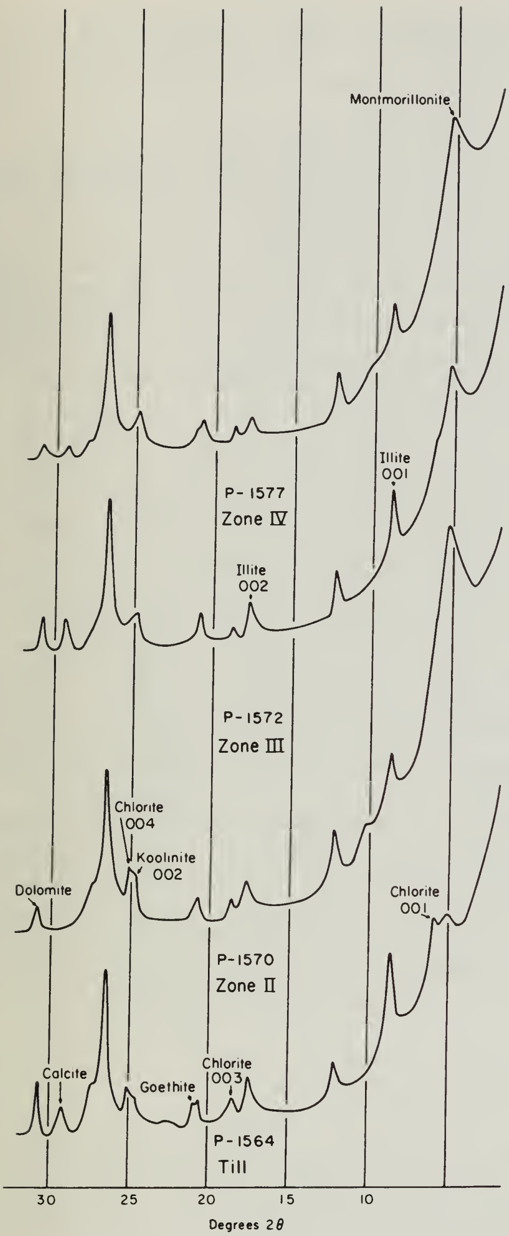


Figure 4 - Typical X-ray diffraction curves of Richland Loess and underlying till at the 10-mile School section showing the compositional zones above Woodfordian age till.

on Normal, Cropsey, Farm Ridge, Marseilles, and younger tills, Zone III loess was found in contact with the till.

Analyses of the compositions of the many Woodfordian tills show two distinct groupings. The tills from the earliest Woodfordian up through the pink Bloomington-Metamora contain a higher percentage of vermiculite and lower content of illite than the gray Normal and younger tills of the Lake Michigan lobe. This change in composition results from the major withdrawal and readvance of the Lake Michigan lobe glacier (Willman and Payne, 1942). Therefore, by both stratigraphic tracing and compositional matching, the boundary between Zones II and III is placed in the glacial sequence between the Bloomington-Metamora and Normal till sheets, with a probable radiocarbon age of 16,500 ± 1000 B.P.

The boundary between Zones II and III is also characterized by a pause in loess deposition, or reduced rate of deposition, as indicated by minor soils. It also must be coincident with a significant glacial retreat and readvance accompanied by the change in glacial flow pattern that gave rise to the compositional change of the tills. The distinctive color change between the tills is not apparent in the loess.

The termination of deposition of Zone III is difficult to date directly. Inconclusive radiocarbon data suggest a probable termination by about 15,000 radiocarbon years B.P. However, an indirect method is available. As the Woodfordian glacial termini retreated into the LaSalle County area and farther east, extensive lakes formed in the Illinois Valley. When the Lake Michigan lobe glaciers retreated still farther, they discharged into Lake Chicago. These lakes served as an effective trap for outwash sediments, and it seems improbable that any significant amount of loess could be derived from the Illinois Valley after about 15,000 radiocarbon years B.P.

The lowermost part of the loess on the Inner Cropsey Moraine is the youngest that appears to be derived from the Illinois Valley. The age of the Cropsey Moraine is not accurately known, but appears to be between 15,000 and 16,000 radiocarbon years B.P.

A thin organic-rich zone found in the lower part of the loess on the Farm Ridge Moraine, but not present in the thinner loess on the younger Marseilles Moraine (Willman and Payne, 1942), may be the contact of Zones III and IV. If so, its age would be represented by the advance of the Marseilles ice.

At the northern end of this traverse, primarily in Putnam, LaSalle, and Bureau Counties, a still higher zone, designated Zone IV, is present at the top of the Richland Loess (figs. 2, 3, and 4). Southward along the valley, thin, and perhaps discontinuous, Zone IV occurs above Zone III at least as far south as Cass County (table 2). This zone is characterized by relatively high montmorillonite and low illite contents and has a composition somewhat similar to Zone II. The loess of Zone IV was blown from the extensive outwash surfaces in Whiteside and Rock Island Counties and adjacent Iowa that were fed from the glacial lobes in northern Iowa, eastern Minnesota, and northwestern Wisconsin. Outwash from the northwest continued to be carried through the Mississippi Valley throughout Woodfordian time and served as a continuing source of loess after the termination of the northeastern loess source. In the area of Putnam and southern LaSalle Counties, this zone overlies Zone III (table 3). Westward in Bureau County, immediately above Bloomington till, the composition of Zone III is modified by the admixture of high montmorillonite material, blown from the outwash area to the west (table 4). This western influence on the composition of Zone III diminished eastward. Also, because the high illite source diminished as a result of formation of Lake Illinois in the Illinois Valley, the percentage of western-derived high montmorillonite sediment increased, so that the boundary between Zones III and IV in this region is gradational. Westward, Zone III is gradationally replaced by high montmorillonite loess from the western source, so that in the Mississippi Valley, Zone IV contains in its lower part the stratigraphic equivalent of Zone III of the Illinois Valley (fig. 5).

Zone IV occurs as a thin veneer on the tills of Marseilles and younger age to the northeast—tills that are younger than the top of Zone III. This stratigraphic position, together with radiocarbon dates from near the Mississippi Valley, establish Zone IV as the youngest unit of the Woodfordian loesses in Illinois.

ZONATION IN THE MISSISSIPPI VALLEY

The second traverse (fig. 1) follows the belt of thick loess along the Mississippi Valley in extreme western Illinois and then eastward through the thick loess along the southern margin of the Green River Lowland to the Big Bend of the Illinois River in Bureau and LaSalle Counties, where it overlaps the Illinois Valley traverse. The zones defined in this body of loess are shown diagrammatically in figure 5. The analytical data for this traverse (fig. 6; tables 4 and 5) are based on 14 sections.

Along this traverse the loess and till do not intertongue, and radiocarbon dates are not abundant, as in the Illinois Valley traverse. In order to establish age relations, it is necessary to correlate the compositional zones of the Mississippi Valley with the zones of the Illinois Valley and to relate the compositions of the zones to the drainage history. Fortunately, a few radiocarbon dates are available from the upper part of the loess along the Mississippi Valley.

TABLE 4 - SELECTED ANALYSES OF RICHLAND AND PEORIA LOESSES IN BUREAU COUNTY

Section	Zone II					Zone III					Zone IV			
	D. I. ratio	Expandable clay minerals (%)	Illite (highest value) (%)	Kaolinite and chlorite (%)	Zone contact relations*	D. I. ratio	Expandable clay minerals (%)	Illite (highest value) (%)	Kaolinite and chlorite (%)	Zone contact relations*	D. I. ratio	Expandable clay minerals (%)	Illite (lowest value) (%)	Kaolinite and chlorite (%)
RICHLAND LOESS														
Buda East						1.4	62	26	12	G	0.8	83	9	8
Walnut SE						1.7	67	24	9	G	1.0	81	12	7
PEORIA LOESS														
Neponset	1.2	64	24	12	S	2.2	48	40	12	G	1.5	76	16	8

*G=gradational; S=sharp

In the southern part of the Mississippi Valley traverse, the lowest zone of the Woodfordian Peoria Loess is called Zone I. Although it is essentially equivalent in age to Zone I of the Illinois Valley, it had a source in the Ancient Iowa drainage system and was derived largely from the high montmorillonite outwash from the Des Moines lobe of Iowa (table 5). The composition of this zone is similar to Zone I in the Ancient Mississippi Valley of northwestern Illinois, which also received high montmorillonite outwash from the northwest. Zone I in the Illinois Valley contains more illite and less montmorillonite than Zone I of the Mississippi Valley.

The boundary between Zone I and Zone II in the Mississippi Valley is less sharp and distinct than the comparable contact in the Morton Loess of the Illinois Valley. This contrast reflects the diversion of the Ancient Mississippi River by the early Woodfordian glacier. As the northwestern drainage was excluded rather suddenly from the Illinois Valley, the change in source is immediately reflected in the loess composition. On the other hand, the compositional change along the Mississippi Valley was caused by a progressively increasing admixture of higher illite outwash from the Green River lobe of the Lake Michigan glacier, and thus the compositional change in the loess was gradational. As Zone II of the Mississippi Valley continued to receive a significant increment from the northwest, its illite content is distinctly below that of Zone II in the Illinois Valley (figs. 3 and 6; tables 2 and 5). Also, the top of Zone II in the Mississippi Valley traverse is transitional

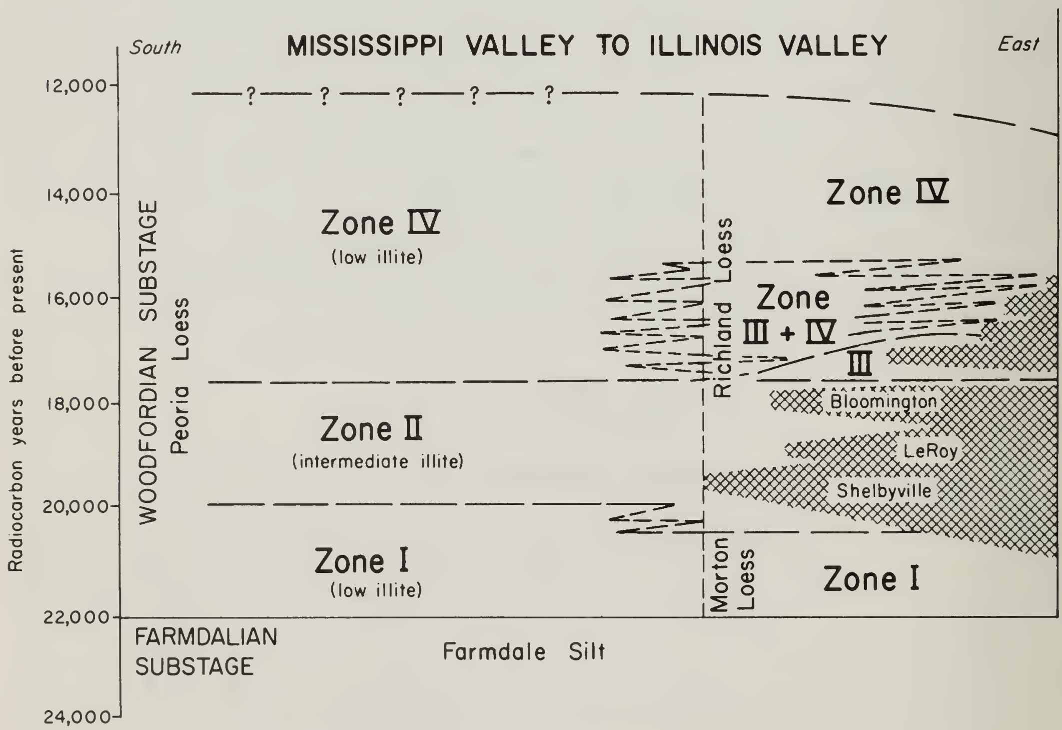


Figure 5 - Generalized diagram showing relation of compositional zones along the Mississippi Valley of western Illinois and their relation to the Illinois Valley.

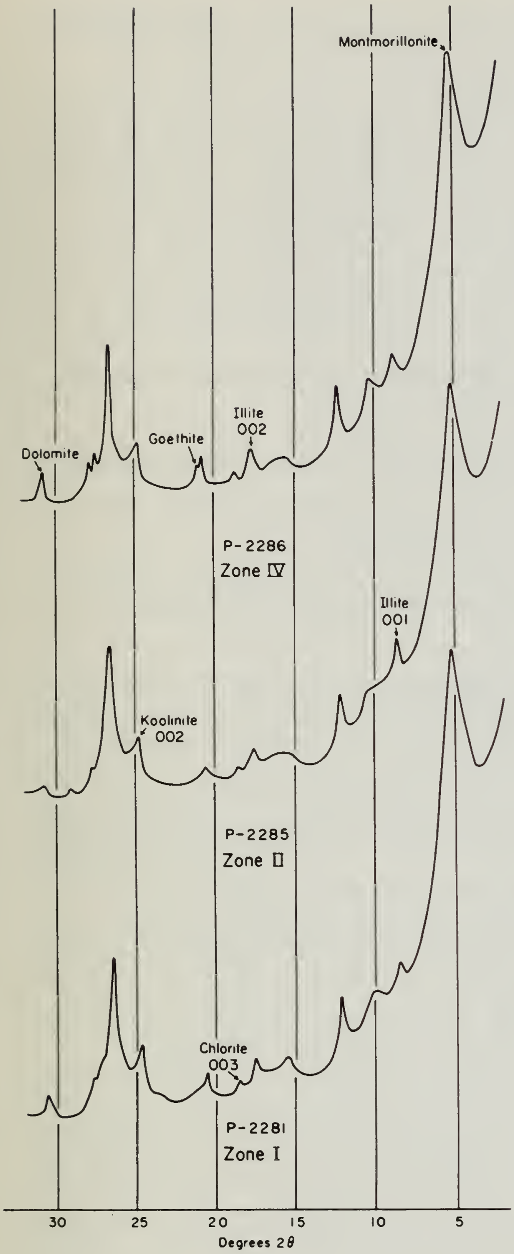


Figure 6 - Typical X-ray diffraction curves of Peoria Loess from the Kirkwood section showing the compositional zones of the Mississippi Valley. Sample P-2286 is at the position of a radiocarbon date of 16,000 ±340 (I-1719).

because this eastern outwash source diminished gradually.

Along all of this traverse, except in the overlap area with the first traverse in the region of the Big Bend of the Illinois, Zone II is directly overlain by Zone IV (fig. 5; table 5). Zone IV shows the return to the high montmorillonite source in the outwash from the Des Moines lobe, augmented by a source, also high in expandable clay minerals, from the headwaters region of the Mississippi River.

The age of Zone IV in the Mississippi Valley is indicated by two radiocarbon dates given to us by Prof. Herman Wascher of the Department of Agronomy of the University of Illinois. A date of 16,000 ± 340 (I-1719) was obtained from the lower part of the zone at the Kirkwood section, and a date of 13,700 ± 230 (I-1720) was obtained from the middle of the zone at the Baldbluff section. These data indicate that the upper part of the calcareous Peoria Loess along the Mississippi Valley of western Illinois is younger than the upper part of the calcareous Peoria Loess along the central Illinois Valley (fig. 5).

INFLUENCE OF SURFACE SOILS ON ZONES

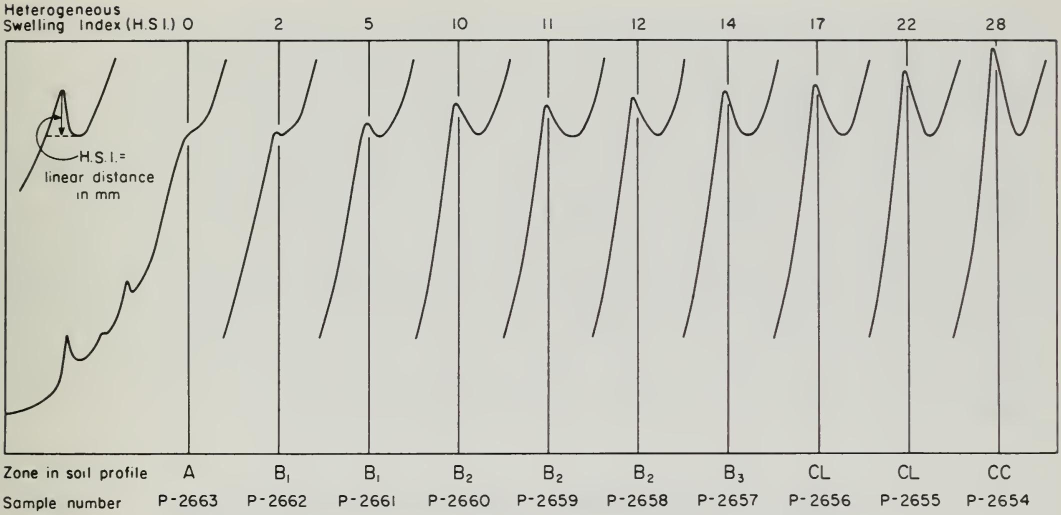
In the surface soil profiles developed on loess, identification of zone boundaries is commonly difficult, if not impossible. Most clay minerals are altered by the effect of weathering. To evaluate the changes produced by weathering, closely spaced samples were taken for analysis from the ground surface downward through the soil profile at several of the sections studied (Buda East, Neponset, Studyvin School, Varna South, Granville). A series of X-ray diffraction curves through the surface soil profile at the Buda East section is shown in figure 7.

Distortion of the indigenous clay-mineral composition is greatest in the A-, B_1-, and B_2-zones, but some modification

TABLE 5 - SELECTED ANALYSES OF PEORIA LOESS ALONG MISSISSIPPI VALLEY TRAVERSE

Section	Zone I					Zone II					Zone IV			
	D. I. ratio	Expandable clay minerals (%)	Illite (lowest value) (%)	Kaolinite and chlorite (%)	Zone contact relations*	D. I. ratio	Expandable clay minerals (%)	Illite (highest value) (%)	Kaolinite and chlorite (%)	Zone contact relations*	D. I. ratio	Expandable clay minerals (%)	Illite (lowest value) (%)	Kaolinite and chlorite (%)
Morrison	0.9	83	10	7	G	1.7	66	24	10	G	0.8	80	11	9
Rapid City (B)	0.7	83	9	8	G	1.2	68	21	11					
Bernard School	0.6	82	9	9	G	1.3	66	22	12	G	1.0	80	12	8
Case Creek	0.7	82	10	8	G	1.4	70	20	10	G	0.8	81	10	9
Wanlock	0.6	77	12	11	G	1.0	74	16	10	G	0.6	74	13	13
Baldbluff											0.8	87	7	6
Little York	0.9	80	12	8	G	2.3	76	19	5	G	1.1	83	10	7
Kirkwood	0.6	87	7	6	G	1.5	77	16	7	G	0.8	87	7	6
Dallas City	0.7	75	13	12	G	1.2	71	18	11	G	0.7	81	10	9
Marcelline						1.4	74	17	9	G	0.7	81	10	9
North Quincy	0.8	78	13	9	G	1.4	71	18	11	G	0.6	82	9	9

*G=gradational; S=sharp



Reduced 60%

Figure 7 - Sequence of X-ray diffraction curves from the Buda East section showing the mineral alteration through the surface soil profile in Richland Loess.

extends down to the B_3-zone and the CL-zone. The most apparent effect of the weathering is the broadening and rounding of the 17 Å peak for montmorillonite on the X-ray diffraction curves. In the A- to B_2-zones of some of these loess soils, this "peak" is rounded to the extent that it appears only as a broad swell on the curve, and, thus, calculations of the amounts of the clay-mineral constituents are not comparable to analyses of the unweathered materials. Such analyses are not included in table 1.

The development of this weathering effect in swelling clays has been discussed (Frye, Willman, and Glass, 1964; Willman, Glass, and Frye, 1966) and has been called heterogeneous swelling material or "B-clay." It is not our purpose here to discuss its origin, other than to re-emphasize that it occurs in the parts of the soil profiles where the less than .5 micron clay is most abundant.

Our method of calculation of the percentages of clay minerals gives misleading results where heterogeneous swelling material is present because the decrease in intensity of the 17 Å peak produces an apparent decrease in montmorillonite and an apparent increase in the other clay minerals, which is an artifact. X-ray diffraction analyses of closely spaced samples permit an evaluation of the relative degree of modification. The heterogeneity of expandable clay minerals in soil profiles, as expressed by the broadening of the first order diffraction peak, is inversely proportional to the vertical linear distance from the commencement of this peak to its maximum height. That is, the smaller the vertical linear distance, the greater the development of heterogeneous swelling material, assuming the parent material was uniform. This heterogeneous swelling index (H.S.I.) is demonstrated in figure 7. Not only is the broadening of the diffraction peak apparent, but the decrease in vertical linear distance as well. The heterogeneous swelling index through the various zones in the soil profile is tabulated in table 6.

The large differences in the shape of the curves are related to the development of heterogeneous swelling material both by in situ weathering and downward illuviation of clay from the upper part of the profile. Diffraction curves that show a decrease in H.S.I. upward through a soil profile should not be used in calculation of clay minerals percentages. The index is significant only in relation to a series of samples in a single profile as a relative estimate of the degree of weathering.

Other modifications in composition are suggested by the apparent minor upward decrease in illite through the B_2-zone, the modification of chlorite through the B-zone, and, in some cases, the apparent pedogenic increase of kaolinite, and perhaps also of vermiculite, in the A-zone.

These facts all lead to the conclusion that compositional data for identification of zones in the loess must be based on samples from below the zone of clay accumulation in the surface soil profile. As a result, the zone descriptions here are based primarily on analyses of loess that contain some carbonate minerals or are from the lower part of the CL-zone. No samples from the B-zone of the surface soil profiles were used in the evaluation of stratigraphic zones.

TABLE 6 — HETEROGENEOUS SWELLING INDEX MEASURED FROM X-RAY DIFFRACTION CURVES FOR BUDA EAST SECTION

Sample	Soil zone	H.S.I. (in mm)
P-2663	A	—
P-2662	B_1	2
P-2661	B_1	5
P-2660	B_2	10
P-2659	B_2	11
P-2658	B_2	12
P-2657	B_3	14
P-2656	CL	17
P-2655	CL	22
P-2654	CC	28

As the time interval that was available for the development of surface soils in Woodfordian loess adjacent to the central Illinois Valley is about 14,000 ± 1000 radiocarbon years, and the time interval for soil development on Zone IV about 12,000 ± 1000 radiocarbon years, comparisons can be made with the degree of mineral alteration shown by the major interglacial soils (Willman, Glass, and Frye, 1966). In the Sangamon Soil, illite decomposition has progressed to a much more advanced degree and to a much greater depth in the profile. The same generality can be drawn for chlorite. In the B-zones of in situ Sangamon Soils, the heterogeneous swelling material commonly dominates, whereas in the slowly accumulating clay of the accretion-gley soils, pedogenic processes have reconstituted the degraded clay material (heterogeneous swelling material) to sharply definitive montmorillonite and vermiculite. Although it is not possible to translate these differences into years, the time interval required for the development of the Sangamon Soil was many orders of magnitude greater than for the surface soils in the top of loess of Woodfordian age.

In some sections along the Illinois Valley (Cottonwood School, Jules, Frederick South, and others), from one to three minor, or incipient, A-C soils have been observed in the upper part of the loess. Although the observed A-zones have not been completely leached of their carbonate minerals, some leaching has taken place, accompanied by the secondary development of small nodules of $CaCO_3$ below the A-zone. The degree of mineral alteration has been quite minor except at the top of the A-zone. A clay-rich B-zone has not been observed in these soils. At the Jules section, analyses were made of closely spaced samples to determine the relation of these soils to the compositional zones. The soils commonly occur at or near the contact of Zones II and III and clearly represent only a brief period of nondeposition of loess, accompanied by soil formation. In this and other sections along this part of the valley, field observations and minerological data suggest several cyclic pauses in deposition in the upper part of the Peoria Loess.

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SELECTED GEOLOGIC SECTIONS

The following are 20 formerly unpublished measured geologic sections from which samples were collected for this study. Samples were also used from 18 additional measured geologic sections that have been published previously. The sample numbers used, for example P-2291, are those used in the tables. The sections are arranged alphabetically by name.

BALDBLUFF SECTION

Roadcut and auger boring in NE$\frac{1}{4}$ NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 20, T. 12 N., R. 4 W., Henderson County, Illinois.

Thickness (feet)

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Peoria Loess
4. Loess, with very fine sand, leached, tan-brown, surface soil 1.5
3. Loess, coarse, with some very fine sand, calcareous, light tan to yellowish light tan; contains fossil snail shells; radiocarbon date determined on snail shells from lower part is 13,700 ± 260 (I-1720). Samples P-2291 to P-2295 downward from top at 1-foot intervals 5.0
2. Loess, coarse, with some very fine sand, calcareous, light tan to yellowish light tan; interbedded with thin zones of fine sand. Sample P-2296, 1 foot below top; P-2297 to P-2299 downward at 1-foot intervals; P-2300 at base 5.5
1. Sand, with some coarse silt, light tan, calcareous, indistinct bedding. Sample P-2301, 1 foot below top; P-2302 to P-2305 downward at 1-foot intervals to bottom of auger hole. (A previous auger boring near this point penetrated 20 feet of sand without going through it) . . . 5.0

Total . . 17.0

BERNARD SCHOOL SECTION

Roadcut and auger boring in SW$\frac{1}{4}$ SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 31, T. 18 N., R. 3 E., Henry County, Illinois.

Thickness (feet)

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Peoria Loess
4. Loess, coarse to very coarse, massive, tan to light yellow-tan, calcareous except in the surface soil at top; contains nodules of $CaCO_3$ in lower part; gradational contact at base. Samples P-3013 to P-3017 from 5 feet above base upward at 5-foot intervals 30.0
3. Loess, coarse, massive, rusty brown to tan and brown streaked, weakly calcareous; sharp contact at base, gradational at top; sample P-3012 . . . . . 1.0

Farmdalian Substage
Farmdale Silt
2. Silt, black to dark gray with organic streaks, leached; contains local secondary $CaCO_3$ nodules; gradational at base. Sample P-3011 top, P-3010 middle 2.0

Altonian Substage
Roxana Silt
1. Silt, becoming clayey downward, dark gray becoming light gray streaked with rusty brown downward, leached; contains nodules

Thickness (feet)

of secondary $CaCO_3$. Samples P-3009 to P-3005 at bottom of auger hole 3.5

Total . . 36.5

BRADFORD EAST SECTION

Roadcut in center sec. 24, T. 14 N., R. 8 E., Bureau County, Illinois.

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Richland Loess

3. Loess, leached, tan and brown; surface soil in top. Sample P-1870, 1 foot above base 5.0
2. Loess, calcareous, tan, massive; bottom ¼-foot contains a few pebbles. Samples P-1869 to P-1866 top to bottom 1.5

Metamora Drift

1. Till, calcareous, pink. Sample P-1865 is top 3 inches 2.0

Total . . 8.5

BUDA EAST SECTION

Roadcut in SE¼ SE¼ SW¼ sec. 31, T. 16 N., R. 8 E., Bureau County, Illinois.

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Richland Loess

8. Loess, leached, dark gray to black, granular structure; A-zone of surface soil. Sample P-2664, 0.2 foot below top; P-2663, 0.7 foot below top 1.0
7. Loess, leached, dark gray with some ash-gray plates, platy structure, tough; B_1-zone of surface soil. Samples P-2662 upper, P-2661 lower 1.0

Thickness (feet)

6. Loess, leached, light brown to yellow-tan, clayey, tough, indistinct blocky structure; grading to yellow-tan in lower part; B_2-zone of surface soil. Samples P-2660 upper, P-2659 middle, P-2658 lower 1.5
5. Loess, leached, yellow-tan to reddish tan, massive; B_3-zone of surface soil. Sample P-2657. . . . . 0.5
4. Loess, leached, massive, compact, light tan-brown; CL-zone of surface soil. Sample P-2656 and P-2025 upper, P-2655 lower, P-2024 base 1.0
3. Loess, calcareous, yellow-tan, massive, friable. Samples P-2654 upper to P-2648 base (P-2023—P-2019 top to base) 3.2

Bloomington Drift

2. Gravel and sand, dominantly dolomite and limestone pebbles with a variety of igneous rocks; indistinctly bedded, calcareous, gray; strongly oxidized to brown at west end of exposure but no indication of leaching 4.0
1. Till (Providence Moraine), massive, calcareous, pinkish tan; sandy till with abundant cobbles and small boulders to level of road ditch. Sample P-2018 . . . . 4.0

Total . . 16.2

CASE CREEK SECTION

Roadcuts in NE¼ NW¼ NW¼ sec. 4, T. 16 N., R. 1 W., Rock Island County, Illinois.

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Peoria Loess

	Thickness (feet)
6. Loess, leached; surface soil in upper part. Sample P-2345, 1 foot above base	7.0
5. Loess, yellow-tan, calcareous, massive; contains fossil snail shells, some rusty banding and black flecks. Sample P-2344 top, and at 1-foot intervals downward P-2343 to P-2334 at base	10.0
4. Loess, weakly calcareous, yellow-tan to tan-brown, nonfossiliferous; sharp contact at base	0.5
Altonian Substage	
Roxana Silt	
3. Loess, brown, leached, massive. Sample P-2333 top	2.0
2. Silt, with some sand and a few small pebbles, leached, brown, massive; colluvium	0.7
Illinoian Stage	
1. Sangamon Soil, B-zone, developed in till, red-brown, clayey; exposed to bottom of road ditch	—
Total	20.2

GRANVILLE AUGER SECTION

Road ditch at NW corner sec. 15, T. 32 N., R. 1 W., Putnam County, Illinois (samples P-2000 to P-2017). Supplementary section sampled in roadcut 200 yards north (samples P-2670 to P-2681).

	Thickness (feet)
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage	
Richland Loess	
3. Loess, leached, massive, surface soil in top. Samples P-2015 base, P-2016 $\frac{1}{2}$-foot above base, P-2017 1 foot above base. (Supplemental samples from adjacent roadcut starting 2 inches below surface and downward at $\frac{1}{2}$-foot intervals: P-2681 to P-2679, A-zone; P-2678 to P-2676, B-zone; P-2675 to P-2674, CL-zone. At this location the CL-zone is 4 feet thick)	5.0
2. Loess, calcareous, tan and gray, massive. Samples P-2003 to P-2014 distributed evenly from bottom to top. (Supplemental samples from top downward at $\frac{1}{2}$-foot intervals: P-2673 to P-2670)	4.5
Cropsey Drift	
1. Till, calcareous, gray, clayey. Samples P-2000 lower; P-2001, P-2002 upper	0.8
Total	10.3

JULES SECTION

Roadcut in SE$\frac{1}{4}$ SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 13, T. 18 N., R. 4 W., Cass County, Illinois.

	Thickness (feet)
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage	
Peoria Loess	
8. Loess, leached, surface soil at top	3.0
7. Loess, light yellow-tan, calcareous, massive, friable. Samples P-1629 to P-1622 from top down at $\frac{1}{2}$-foot intervals; P-1620 base; P-1621, $\frac{1}{4}$-foot above base	4.0
6. Loess, weakly developed A-C soil profile, gray, weakly calcareous; contains small caliche nodules in middle and lower part; incipient columnar structure in upper part. Samples P-1619 to P-1611 from top to bottom at $\frac{1}{4}$-foot intervals	2.0

Thickness (feet)

5. Loess, calcareous, yellow-tan, massive. Samples P-1602 to P-1610 upward from base at ½-foot intervals. 4.5
4. Not accessible for sampling 15.0

Section below is sampled in lower part of roadcut.

3. Loess, tan to gray streaked with rusty tan, calcareous, massive, compact. Samples P-1635 to P-1639 from base upward at 1-foot intervals; P-1640, 9 feet above base; P-1641, 13 feet above base 15.0
2. Loess (transition zone at base of Peoria Loess), calcareous, pale pinkish tan to light gray-purple. Sample P-1633, ½-foot above base; P-1634, 1 foot above base 2.0

Altonian Substage
Roxana Silt

1. Loess, leached, pink, massive, to bottom of exposure. Samples P-1632 to P-1630 from top downward at 1-foot intervals. 2.0

Total . . 47.5

KIRKWOOD SECTION

Roadcut and auger boring in road ditch in SW¼ SE¼ SW¼ sec. 32, T. 11 N., R. 3 W., Warren County, Illinois.

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Peoria Loess

6. Loess, leached, tan to light brown; surface soil in top. Sample P-2289, 1 foot above base; P-2290, 2 feet above base 4.0
5. Loess, calcareous, tan, massive, compact; contains fossil snail shells throughout; radiocarbon date on shells 1 to 2 feet below top is 16,000 ±340 (I-1719). Samples P-2288 through P-2281 from top downward at 1-foot intervals 7.0
4. Loess (basal transition zone), brown to yellow-brown, weakly calcareous. Sample P-2280 . . . . 1.0

Farmdalian Substage
Farmdale Silt

3. Silt, non-calcareous, gray to dark gray grading downward to yellowish brown at base. Sample P-2279 top, P-2278 lower 1.5

Altonian Substage
Roxana Silt

2. Silt, sandy with a few very small pebbles, noncalcareous, brown to gray-brown, massive. Sample P-2277 top, P-2276 middle, P-2275 bottom 1.5

Illinoian Stage

1. Sangamon Soil developed in till; strongly developed red-brown B-zone, contains abundant Mn-Fe pellets and clay. To bottom of auger hole. Samples P-2274 to P-2270 downward at 1/3-foot intervals 1.3

Total . . 16.3

LITTLE YORK SECTION

Roadcut and auger hole in NE¼ NE¼ NE¼ sec. 19, T. 12 N., R. 3 W., Warren County, Illinois.

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Peoria Loess

4. Loess, leached; surface soil in top 5.0
3. Loess, calcareous, tan, massive; contains a few

Thickness (feet)

fossil snail shells in lower part. Samples P-2318 to P-2314 upper to lower 6.0

2. Loess, sandy, calcareous, tan. Samples P-2313 to P-2309 upper to lower 5.0

Pre-Woodfordian

1. Sand, leached, tan-brown. Samples P-2308 to P-2306 upper to base 3.5

Total . . 19.5

MORRISON SECTION

Overburden of limestone quarry as it existed on August 3, 1966, in SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 7, T. 21 N., R. 5 E., Whiteside County, Illinois.

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Peoria Loess

8. Loess, coarse, massive, yellow-tan, calcareous below deeply developed surface soil; locally, sandy zones in lower part. Samples starting 1$\frac{1}{2}$ feet above base distributed upward through calcareous loess at 1$\frac{1}{2}$-foot intervals HK-109-11 to 28 . . . . . 37.0

7. Loess, coarse, tan-brown, weakly calcareous; locally crenulate banding of brown; transitional at top but sharp contact at base. Sample HK-109-10 . . . . 1.0

Altonian Substage
Roxana Silt

6. Silt with clay and some fine sand, chocolate brown, leached, micro-blocky structure below top $\frac{1}{2}$-foot; micro-blocky peds are capped with thin layer of white very fine quartz sand, to coarse silt; lower 1 foot is sandy and clay skins are present; has general appearance of A_2- to B_1-zone below top $\frac{1}{2}$-foot. Sample HK-109-6 is $\frac{1}{2}$-foot above base; HK-109-7 to 9 spaced at 1-foot intervals upward 4.0

Illinoian Stage
Loveland Silt

5. Sangamon Soil developed in silt and fine sand: A-zone, dark brown to reddish brown, gradational at top and bottom, micro-blocky, leached; some clay skins. Sample HK-109-5 . . . . 0.7

4. Sangamon Soil developed in silt and fine sand: B_2-zone, red-brown, micro-blocky with well developed clay skins and small pellets of Mn-Fe 1.0

Liman Substage
Mendon Drift

3. Sangamon Soil developed in till: B_2-zone, red-brown, micro-blocky with well developed clay skins and pellets of Mn-Fe. Sample HK-109-4 at top 1.5

2. Sangamon Soil developed in till: B_3-zone, reddish tan-brown, indistinct blocky structure, a few small pellets of Mn-Fe. Sample HK-109-3 middle . . 1.5

1. Till, leached, tan-brown, massive to platy; CL-zone of Sangamon Soil; leached; resting on dolomite at top of quarry face. Samples HK-109-1 at base; HK-109-2, 2$\frac{1}{2}$ feet above base 4.0

Total . . 50.7

MT. PALATINE AUGER SECTION

Road ditch in SW$\frac{1}{4}$ SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 1, T. 31 N., R. 1 W., Putnam County, Illinois.

Pleistocene Series
Wisconsinan Stage

Thickness (feet)

Woodfordian Substage
Richland Loess
3. Loess, leached, surface soil in top. Sample P-1999 middle 4.5
2. Loess, calcareous, tan, massive. Sample P-1997 base, P-1998 top 1.0

Cropsey Drift
1. Till, calcareous, gray, clayey. Samples P-1994, P-1995, P-1996 . . . . 0.8

Total . . 6.5

NEPONSET SECTION

Roadcut in NW$\frac{1}{4}$ SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 34, T. 16 N., R. 6 E., Bureau County, Illinois.

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Peoria Loess
6. Loess, leached, dark gray to black, granular structure; A-zone of surface soil. Sample P-2647, $\frac{1}{2}$-foot below top 0.8
5. Loess, leached, mottled dark gray and brown; B_1-zone of surface soil. Sample P-2646 . . . . 0.5
4. Loess, leached, clay-rich, brown to tan-brown; B_2-zone of surface soil. Sample P-2645 . . . . 0.6
3. Loess, leached, light brown to tan-brown with some mottling; some krotovenas in upper part; B_3-zone of surface soil. Samples P-2644 top to P-2641 bottom 1.8
2. Loess, leached, tan, massive; contains some small pellets of Mn-Fe; CL-zone of surface soil. Sample P-2640 . . . . 0.5
1. Loess, calcareous, tan, massive; contains a few small Mn-Fe pellets in upper part. Samples P-2639 to P-2635 at $\frac{1}{2}$-foot intervals from top; P-2634 to P-2627 at 1-foot intervals downward; P-2626, 2 feet lower at base 12.3

Total . . 16.5

PARTRIDGE CREEK SECTION

Roadcut in SE$\frac{1}{4}$ NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 33, T. 28 N., R. 3 W., Woodford County, Illinois.

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Richland Loess
4. Loess, leached; surface soil in top has a strong red-brown B-zone. Sample P-1560, 1$\frac{1}{2}$ feet below surface; P-1559, 2$\frac{1}{2}$ feet below surface 3.0
3. Loess, calcareous, gray with tan streaks and some mottling, some dispersed limonite tubules. Samples P-1558 to P-1549 distributed from top to base at $\frac{1}{2}$-foot intervals 4.5

Metamora Drift
2. Sand and gravel outwash, gray sand interzoned with brown to rusty brown sand and gravel; some nodular caliche in upper part. Samples P-1548, $\frac{1}{2}$-foot down; P-1547, 1$\frac{1}{2}$ feet down 2.5
1. Till, calcareous, pink-tan. Sample P-1546 . . . . 0.5

Total . . 10.5

PEKIN SOUTH SECTION

Roadcut and auger boring in NW$\frac{1}{4}$ NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 30, T. 24 N., R. 4 W., Tazewell County, Illinois.

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Peoria Loess

	Thickness (feet)
5. Loess, gray, granular, leached; A-zone of surface soil. Sample P-2715	0.8
4. Loess, red-brown, blocky, clayey, grading downward into tan-brown, massive, leached; B-zone and CL-zone of surface soil. Sample P-2714, ½-foot below top; P-2713, 2 feet below top; P-2712, 3½ feet below top	4.2
3. Loess, massive, tan, calcareous; contains some tubules of limonite and some mottling with gray. Sample P-2711, 1 foot below top; P-2710, 2½ feet below top; P-2709, 6½ feet below top; P-2708, 13½ feet below top; P-2707, 14½ feet below top; P-2706, 15½ feet below top; P-2705 to P-2703 at ½-foot intervals	17.0
Altonian Substage	
Roxana Loess	
2. Loess, pink to pink-tan, massive, weakly calcareous, locally leached; concretions of $CaCO_3$ common in upper half. Samples P-2702 to P-2697 distributed from top downward at ½-foot intervals	3.5
Roxana Silt—Zone I	
1. Silt, with some fine sand and clay, a few small pebbles in lower part, leached, tough, gray-tan to tan. Samples P-2696 top, P-2695 middle, P-2694 bottom	0.5
Total	26.0

RAPID CITY (B) SECTION

Fresh cuts along north side of interchange to Interstate 80 across Mississippi River in SE¼ sec. 3, T. 18 N., R. 1 E., Rock Island County, Illinois.

	Thickness (feet)
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage	
Peoria Loess	
9. Loess, leached; surface soil in upper part. Sample P-2361, B_2-zone; P-2360, B_3-zone	8.0
8. Loess, tan, calcareous, coarse, massive; contains some mottling and limonite tubules and sparse snail shells. Sample P-2453 top; P-2452, 6 feet above base; P-2451, 2 feet above base. (In next cut south, samples P-2359 to P-2353 from top to bottom at 2½-foot spacing)	26.0
7. Loess, gray, calcareous, coarse, massive; contains fossil snail shells. Sample P-2450 upper, P-2449 lower. (In next cut south, P-2352 middle)	2.0
Farmdalian Substage	
Farmdale Silt	
6. Loess, dark tan, noncalcareous, massive. Sample P-2448	0.5
5. Silt, with some fine sand, dark gray, leached, massive; contains charcoal flakes. Sample P-2447 upper, P-2446 lower. (In next cut south, P-2351 upper). In cut to south, cryoturbations are prominently developed	2.0
Sangamonian Stage	
Sangamon Soil	
4. Sangamon Soil accretion-gley; clay, gray with indistinct streaks of dark gray, massive; a few small pebbles throughout; noncalcareous. Samples P-2445 to P-2443 top to bottom	3.5
Illinoian Stage	
Liman Substage	
3. Till, oxidized and leached, irregular contact at base. Samples P-2442 to P-2439 from top to bottom	3.5

	Thickness (feet)
2. Till, oxidized, calcareous, massive, tan-brown; gradational at base. Samples P-2438 to P-2436 from top to bottom	3.5
1. Till, calcareous, compact, blue-gray, massive and jointed. Samples P-2435 to P-2430 from top to bottom. (To north, a lower cut exposes the base of this till on calcareous sand)	31.0
Total . .	80.0

STUDYVIN SCHOOL SECTION

Roadcut in $NE\frac{1}{4}SW\frac{1}{4}NW\frac{1}{4}$ sec. 22, T. 23 N., R. 4 W., Tazewell County, Illinois.

	Thickness (feet)
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage	
Richland Loess	
8. Loess, coarse, gray, leached, platy structure lower part; A-zone of surface soil. Sample P-2743X	0.6
7. Loess, coarse, tan-brown, with gray streaks and coating of gray very fine sand on surface of peds, prismatic to irregularly blocky; B_1-zone of surface soil; gradational top and bottom. Sample P-2742X	0.6
6. Loess, coarse, reddish tan-brown, leached, clayey, indistinct blocky structure; B_2-zone of surface soil; gradational top and bottom. Samples P-2741X upper, P-2740X middle, P-2739X lower	3.0
5. Loess, coarse, reddish tan-brown, grading downward to tan with mottles of pale pinkish tan-brown, leached, massive; B_3-zone of surface soil. Samples P-2738X upper, P-2737X middle, P-2736X lower	3.0
4. Loess, coarse, calcareous, tan, massive. Samples P-2735X upper, P-2734X middle, P-2733X base	2.5
3. Loess, sandy, calcareous, tan, massive, gradational top and bottom. Sample P-2732X	1.5
2. Sand, fine, calcareous, tan, massive. Samples P-2731X upper, P-2730X middle, P-2729X lower	3.8
LeRoy Drift	
1. Till, calcareous, gray, massive; sandy and loose in upper part. Sample P-2728X top, P-2727X $1\frac{1}{2}$ feet below top. Irregular erosional contact at top of till; locally, with boulders, cobbles, gravel and sand with thin stringers of till and blocks of silt in low areas of unconformable surface. Sample P-2726X . . .	2.0
Total . .	17.0

10-MILE SCHOOL SECTION

Roadcut in $SE\frac{1}{4}$ $NW\frac{1}{4}$ $SW\frac{1}{4}$ sec. 12, T. 26 N., R. 4 W., Tazewell County, Illinois.

Pleistocene Series
Wisconsinan Stage
Woodfordian Substage
Richland Loess

2. Loess, yellow-tan to tan, tan-brown in upper part, massive, calcareous below surface soil in top, which has been truncated by erosion; the basal $\frac{1}{2}$-foot deposited in water as indicated by presence of Lynmaea and Gyraulus, but the aquatic snails disappear upward and are replaced by terrestrial forms (Leonard and Frye, 1960).

	Thickness (feet)
Sample P-1565 at base; P-1566 to P-1578 at $\frac{1}{2}$-foot intervals upward from base to $6\frac{1}{2}$ feet	8.0
Bloomington Drift	
1. Till, pink, calcareous, massive. Sample P-1564 at top; sharp contact with overlying loess	10.0+
Total	18.0+

VARNA SOUTH SECTION

Roadcut in SW$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 33, T. 30 N., R. 1 W., Marshall County, Illinois.

	Thickness (feet)
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage	
Richland Loess	
7. Loess, leached, dark gray to black, granular structure; A-zone of surface soil. Sample P-2693 top, P-2692, $\frac{1}{2}$-foot below top	0.8
6. Loess, leached, dark gray mottled with some brown to light brown, indistinct blocky structure; B_1-zone of surface soil; sharp contact at base. Sample P-2691	0.6
5. Loess, leached, brown, tough, indistinct structure; contains krotovenas in upper and middle part; B_2-zone of surface soil. Sample P-2690 upper, P-2689 lower (also P-1993)	0.8
4. Loess, leached, tan-brown, compact, massive; CL-zone of surface soil. Sample P-2688 (also P-1992)	0.8
3. Loess, calcareous, tan to yellow-tan with some mottling, massive, compact. Samples P-2687 to P-2685, top to bottom (also P-1991 to P-1988)	1.5
2. Loess, with some pebbles; pebbles more abundant in lower part; calcareous, tan. Sample P-2684 (also P-1987) top, P-2683 (also P-1986) bottom	0.5
Cropsey Drift	
1. Till, calcareous, gray, massive; to level of road ditch. Sample P-2682 (also P-1985)	1.0
Total	6.0

WALNUT SE AUGER SECTION

NE$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 1, T. 17 N., R. 8 E., Bureau County, Illinois.

	Thickness (feet)
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage	
Richland Loess	
5. Loess, leached, tan; surface soil in top. Sample P-2438A at base	6.5
4. Loess, calcareous, yellow-tan with some mottling of gray to gray-tan; contains a few limonite tubules; sparse fossil snail shells in lower part. Samples P-2437A upper to P-2431A lower	5.5
3. Loess, sandy, calcareous, tan. Sample P-2430A upper, P-2429 lower	1.0
Bloomington Drift	
2. Sand and gravel, calcareous, tan to brown. Sample P-2428 upper, P-2427 middle, P-2426 lower	1.5
1. Till, calcareous, pink-tan, to bottom of auger hole. Sample P-2425	0.5
Total	15.0

WANLOCK SECTION

Pit in NE$\frac{1}{4}$ NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 4, T. 14 N., R. 2 W., Mercer County, Illinois.

	Thickness (feet)
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage	
Peoria Loess	
6. Loess, surface soil in top, tan to tan-brown with some mottling of gray, compact, massive; calcareous and contains sparse fossil snail shells in lower part. Samples P-2324 to P-2332 from base upward at 1-foot intervals to 6 feet from top.	14.0
5. Loess (transition zone at base of Peoria Loess), weakly calcareous to noncalcareous, dark tan to light brown; gradational at top. Sample P-2323	1.0
Altonian Substage	
Roxana Silt	
4. Silt, leached, brown; contains some zones of charcoal flakes and locally some fine sand, compact. Sample P-2322 upper	2.0
Roxana Silt—Zone I	
3. Silt, sandy, with a few small pebbles, leached, brown to reddish brown, massive. Samples P-2320 lower, P-2321 top	1.5
Illinoian Stage	
2. Sangamon Soil developed in till; B-zone leached, red-brown, clayey, tough, Mn-Fe streaks and pellets; grading downward to gray, leached till. Sample P-2319, 2 feet below top. Lower part of bed penetrated in auger hole	6.5
1. Sand, leached, tan-brown, penetrated in auger hole	1.0
Total	26.0

TABLE 1 — X-RAY DIFFRACTION ANALYSES

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
BALDBLUFF SECTION							
P-2291	—	—	*	*	*	*	17
2292	—	—	0.7	80	10	10	28
2293	—	—	0.7	86	7	7	35
2294	—	—	0.7	85	8	7	37
2295	9	8	0.7	85	8	7	37
2296	—	5	0.8	87	7	6	44
2297	—	12	0.8	86	8	6	41
2298	17	12	1.1	82	11	7	35
2299	32	6	1.1	80	13	7	34
2300	16	9	1.0	80	12	8	33
2301	7	7	1.1	80	13	7	36
2302	7	8	1.1	80	13	7	39
2303	9	14	1.1	67	21	12	23
2304	15	33	1.5	64	25	11	23
2305	22	13	1.0	83	10	7	35
BERNARD SCHOOL SECTION							
P-3017	13	18	1.1	80	12	8	22
3016	6	14	1.0	71	17	12	16
3015	8	23	1.3	67	22	11	15
3014	6	22	1.3	66	22	12	14
3013	—	21	1.1	65	22	13	12
3012	—	—	0.6	82	9	9	28
3011	—	—	0.3	64	12	24	
3010	—	—	0.4	70	12	18	
3009	—	—	0.3	70	10	20	
3008	—	—	0.3	60	14	26	
3007	—	—	0.6	58	16	26	
3006	—	—					
3005	—	—	0.6	59	20	21	
BRADFORD EAST SECTION							
P-1870	—	—	1.4	71	19	10	16
1869	—	8	1.4	64	24	12	15
1868	—	9	2.0	60	30	10	16
1867	8	20	1.8	58	31	11	11
1866	8	20	2.1	60	30	10	14
1865	20	25	3.1	28	59	13	
BUDA EAST SECTION							
P-2664	—	—	*	*	*	*	0
2663	—	—	*	*	*	*	0

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
BUDA EAST SECTION Cont.							
P-2662	—	—	*	*	*	*	2
2661	—	—	*	*	*	*	5
2660	—	—	*	*	*	*	10
2659	—	—	*	*	*	*	11
2658	—	—	*	*	*	*	12
2657	—	—	*	*	*	*	14
2656	—	—	*	*	*	*	17
2655	—	—	0.8	82	10	8	22
2654	—	10	0.8	83	9	8	28
2653	—	11	0.9	79	11	10	26
2652	15	17	0.9	76	14	10	24
2651	13	11	1.6	77	16	7	23
2650	16	21	1.7	74	19	7	24
2649	19	17	1.0	80	12	8	27
2648	16	23	1.6	73	19	8	20
2025	—	—	*	*	*	*	9
2024	—	—	1.0	77	14	9	16
2023	12	23	1.1	71	18	11	18
2022	40	32	1.2	74	17	9	19
2021	22	26	1.2	73	18	9	16
2020	21	31	1.3	75	17	8	19
2019	22	40	1.4	62	26	12	14
2018	50	58	3.2	16	69	15	
CASE CREEK SECTION							
P-2345	—	—	1.5	76	16	8	23
2344	—	11	1.1	76	15	9	22
2343	—	16	1.4	74	18	8	23
2342	9	14	1.4	74	18	8	20
2341	7	17	0.9	75	15	10	23
2340	4	13	0.8	76	13	11	21
2339	9	12	0.8	81	10	9	22
2338	—	9	0.9	76	14	10	23
2337	6	7	1.4	72	19	9	21
2336	7	13	1.1	69	20	11	21
2335	9	14	1.3	70	20	10	21
2334	—	—	0.7	82	10	8	25
2333	—	—	0.4	76	10	14	
DALLAS CITY SECTION (Frye, Glass, and Willman, 1962)							
P-1248	—	12	0.7	76	13	11	17
1247	—	12	0.8	80	11	9	19

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
DALLAS CITY SECTION Cont.							
P-1246	—	18	0.8	80	11	9	23
1245	—	16	0.7	81	10	9	23
1244	—	21	1.1	71	18	11	18
1243	—	22	1.2	71	18	11	15
1242	—	5	0.7	75	13	12	20
1241	—	—	0.4	69	11	20	
DANVERS SECTION (Glass, Frye, and Willman, 1964)							
P- 558	10	145		10	67	23	
1339	—	90	1.5	28	49	23	6
1338	7	180	1.0	42	34	24	10
1337	6	110	1.2	37	41	22	8
1336	—	85	1.1	31	42	27	8
1335	7	115	0.8	50	27	23	12
1334	—	130	0.9	52	27	21	10
1333	—	120					
1332	—	90					
1331	—	90	0.8	50	28	22	15
1330	—	80	0.8	52	26	22	12
1329	—	135					
1328	—	55	0.6	52	22	26	13
1327	—	45	0.5	54	21	25	13
1326	—	55	0.5	60	19	21	14
1325	—	40	0.8	66	20	14	15
ELDRED SECTION (Frye, Glass, and Willman, 1962)							
P- 944	—	10	2.3	57	33	10	9
943	—	11	1.9	57	32	11	11
942	—	15	2.0	56	33	11	10
941	—	10	1.2	58	27	15	11
940	—	7	1.2	63	24	13	12
939	—	12	1.6	57	30	13	11
938	—	12	1.4	62	26	12	10
937	—	17	1.0	61	24	15	5
936	—	—	0.7	61	19	20	
FARM CREEK SECTION (Gore, 1952)							
P-2186	—	—	1.6	66	23	11	8
2185	—	—	1.6	66	24	10	9

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
FARM CREEK SECTION Cont.							
P-2184	—	—	2.3	60	31	9	6
2183	—	—	2.2	63	29	8	8
2182	—	—	2.2	50	39	11	8
2181	—	—	1.8	63	27	10	12
2180	—	—	1.9	67	24	9	9
2179	—	14	1.1	58	27	15	11
2178	—	14	1.0	56	27	17	10
2177	—	14	0.9	58	24	18	13
2176	—	15	0.8	59	23	18	13
2175	—	17	0.7	60	21	19	16
2174	—	16	0.9				
2173	—	15	0.6	66	17	17	16
2172	—	14	0.7	63	19	18	14
2171	—	13	0.7	59	22	19	12
2170	6	9	0.7	60	21	19	11
2169	3	12	0.6	63	18	19	12
2168	—	—	0.3	66	11	23	
2167	—	—	0.4	67	11	22	
2166	—	—	0.2	70	7	23	
2165	—	—	0.2	77	6	17	
2164	—	—	0.2	56	6	38	
2163	—	—	0.2	42	13	45	
2162	—	—	0.2	51	11	38	
FREDERICK SOUTH SECTION (Frye, Glass, and Willman, 1962)							
P- 600	—	—	*	*	*	*	4
599	—	22	2.1	54	37	9	5
598	—	10	1.9	54	34	12	10
597	—	9	1.0	66	21	13	16
596	—	9	1.0	65	21	14	16
595	—	10	0.6	69	15	16	12
594	—	—	0.6	55	22	23	
GRANVILLE SECTION							
P-2681	—	—	*	*	*	*	0
2680	—	—	*	*	*	*	5
2679	—	—	*	*	*	*	8
2678	—	—	1.0	72	17	11	14
2677	—	—	1.1	75	16	9	14
2676	—	—	1.2	71	19	10	14
2675	—	—	1.4	70	20	10	12

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
GRANVILLE SECTION Cont.							
P-2674	—	—	1.2	69	20	11	12
2673	7	8	1.8	70	22	8	17
2672	11	11	1.5	70	21	9	17
2671	—	12	1.2	67	21	12	18
2670	7	13	1.2	67	21	12	18
2017	—	—	1.1	74	16	10	20
2016	—	—	1.0	72	17	11	21
2015	—	—	1.1	67	21	12	18
2014	—	25	1.3	67	24	9	17
2013	—	20	1.6	69	22	9	14
2012	—	30	1.5	62	26	12	12
2011	—	18	1.5	70	21	9	17
2010	21	30	1.3	67	22	11	16
2009	—	32	1.9	62	28	10	14
2008	—	32	1.6	59	29	12	11
2007	—	28	1.7	62	27	11	15
2006	—	30	2.2	51	38	11	11
2005	3	25	2.3	56	34	10	11
2004	—	25	1.8	52	35	13	10
2003	13	28	2.1	59	31	10	12
2002	14	25	6.9	8	84	8	
2001	18	36	5.1	7	83	10	
2000	17	36	6.7	9	83	8	
HILLVIEW SECTION (Frye, Glass, and Willman, 1962)							
P- 933	—	12	1.6	32	48	20	6
932	—	15	1.0	55	27	18	8
931	—	8	0.7	56	22	22	9
930	—	14	0.9	58	25	17	9
929	—	16	1.5	50	35	15	9
928	—	12	1.5	57	30	13	8
927	—	13	1.1	64	23	13	8
926	—	—	0.5	63	17	20	
JULES SECTION							
P-1629	—	17	1.5	68	22	10	18
1628	6	13	1.6	67	23	10	17
1627	6	11	2.0	61	29	10	16
1626	7	12	1.8	59	30	11	14
1625	—	11	1.8	55	33	12	13
1624	—	21	1.8	55	33	12	9

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
JULES SECTION Cont.							
P-1623	—	15	1.7	53	34	13	10
1622	—	17	2.1	42	44	14	9
1621	—	20	2.3	43	45	12	6
1620	—	18	2.0	46	46	8	8
1619	7	18	1.7	66	24	10	14
1618	—	11	2.2	66	26	8	15
1617	—	15	1.9	62	28	10	15
1616	—	10	1.5	65	24	11	14
1615	—	15	1.9	56	33	11	12
1614	—	7	1.9	61	29	10	14
1613	—	12	2.1	56	34	10	10
1612	—	10	1.6	63	26	11	14
1611	—	14	1.6	67	23	10	17
1610	—	11	1.9	50	37	13	8
1609	—	15	2.9	37	53	10	5
1608	—	13	3.1	39	50	11	4
1607	—	14	2.3	30	57	13	3
1606	—	12	2.3	44	43	13	7
1605	—	16	3.0	41	48	11	5
1604	—	12	2.6	31	55	14	3
1603	—	15	4.0	35	56	9	3
1602	—	14	3.4	34	55	11	4
1641	—	18	1.5	60	27	13	3
1640	—	40	1.6	65	25	10	11
1639	—	35	1.5	62	27	11	10
1638	—	26	1.5	66	24	10	15
1637	—	26	1.5	67	23	10	15
1636	—	22	1.5	68	22	10	15
1635	—	25	1.4	66	23	11	9
1634	—	8	0.6	64	17	19	12
1633	—	—	0.6	66	16	18	14
1632	—	—	0.4	72	13	15	
1631	—	—	0.5	72	13	15	
1630	—	—	0.5	73	12	15	
KIRKWOOD SECTION							
P-2290	—	—	*	*	*	*	22
2289	—	—	0.9	89	7	4	39
2288	14	12	0.8	86	7	7	37
2287	—	11	0.8	82	10	8	31
2286	—	13	0.9	87	7	6	34
2285	—	15	1.5	77	16	7	31
2284	—	19	0.9	82	11	7	30

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
KIRKWOOD SECTION Cont.							
P-2283	—	7	0.7	83	8	9	30
2282	—	14	0.7	86	7	7	41
2281	—	14	0.7	87	7	6	37
2280	—	8	0.6	81	9	10	27
2279	—	—	0.3	83	5	12	
2278	—	—	0.3	80	6	14	
2277	—	—	0.3	68	9	23	
2276	—	—	0.3	63	12	25	
2275	—	—	0.3	62	12	26	
2274	—	—	0.3	63	11	26	
2273	—	—	0.3	63	12	25	
2272	—	—	0.4	65	13	22	
2271	—	—	0.3	65	12	23	
2270	—	—	0.4	67	12	21	
LITTLE YORK SECTION							
P-2318	—	—	1.1	83	10	7	28
2317	—	—	1.4	80	14	6	23
2316	—	—	1.3	84	10	6	32
2315	—	—	2.3	76	19	5	30
2314	—	13	1.1	74	16	10	24
2313	—	8	1.1	77	14	9	25
2312	—	7	1.0	77	14	9	25
2311	—	9	0.9	76	14	10	26
2310	—	8	0.9	80	12	8	27
2309	—	7	0.9	80	12	8	30
2308	—	—	0.8	62	21	17	11
2307	—	—	0.9	70	18	12	19
2306	—	—	1.3	64	24	12	19
MARCELLINE SECTION (Frye and Willman, 1965)							
P-1234	—	—	*	*	*	*	11
1233	—	—	1.3	79	14	7	27
1232	—	15	0.7	74	13	13	20
1231	—	10	1.3	69	20	11	21
1230	—	5	1.2	69	20	11	18
1229	—	—	0.6	47	26	27	
958	—	—	0.8	80	11	9	19
957	—	—	0.8	81	10	9	25
956	—	—	1.4	74	17	9	23
955	—	—	0.5	58	18	24	

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
MARQUETTE HEIGHTS SECTION (Gore, 1952)							
P-2201	—	—	*	*	*	*	0
2200	—	—	1.0	69	19	12	5
2199	—	—	1.2	69	21	10	7
2198	—	—	1.2	65	23	12	8
2197	—	—	1.6	68	23	9	15
2196	6	14	2.0	66	25	9	18
2195	5	18	1.9	58	31	11	15
2194	12	14	1.8	59	30	11	18
2193	8	12	2.2	50	39	11	12
2192	4	15	2.2	46	42	12	11
2191	13	16	2.2	49	39	12	8
2190	8	12	2.2	43	44	13	7
2189	12	14	1.5	64	25	11	16
2188	—	8	1.2	67	21	12	19
2187	12	20	2.3	28	56	16	
MORRISON SECTION							
HK-109-28	—	12	0.8	80	11	9	26
27	9	13	1.0	80	12	8	25
26	6	10	1.3	77	15	8	20
25	12	4	1.2	77	15	8	25
24	11	14	1.3	77	15	8	22
23	19	18	1.4	77	16	7	19
22	21	17	1.2	75	16	9	16
21	17	12	1.6	74	18	8	17
20	11	17	1.7	69	22	9	13
19	10	19	1.7	66	24	10	10
18	13	15	1.2	72	18	10	15
17	16	10	1.2	72	18	10	16
16	10	7	1.3	74	17	9	16
15	20	16	1.2	75	16	9	17
14	10	16	1.3	72	18	10	15
13	10	11	1.2	72	18	10	17
12	13	8	1.0	75	15	10	18
11	—	8	0.9	69	18	13	17
10	—	—	0.9	83	10	7	24
9	—	—	0.5	83	7	10	
8	—	—	0.5	80	8	12	
7	—	—	0.4	74	10	16	
6	—	—	0.4	77	9	14	
5	—	—	0.7	68	16	16	
4	—	—	3.0	26	61	13	

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
MORRISON SECTION Cont.							
HK-109-3	—	—	3.1	37	52	11	
2	—	—	3.2	29	59	12	
1	—	—	0.4	46	22	32	
MT. PALATINE SECTION							
P-1999	—	—	1.1	68	20	12	10
1998	—	30	1.6	59	29	12	13
1997	—	27	1.5	59	28	13	14
1996	14	43	3.4	7	78	15	
1995	13	48	4.2	3	84	13	
1994	15	30	4.6	5	83	12	
NEPONSET SECTION							
P-2647	—	—	*	*	*	*	1
2646	—	—	*	*	*	*	3
2645	—	—	*	*	*	*	7
2644	—	—	*	*	*	*	9
2643	—	—	*	*	*	*	10
2642	—	—	*	*	*	*	13
2641	—	—	*	*	*	*	11
2640	—	—	1.3	71	19	10	15
2639	—	6	1.5	76	16	8	21
2638	—	5	1.3	73	18	9	19
2637	5	15	1.6	68	23	9	16
2636	10	11	1.4	71	20	9	14
2635	7	11	1.4	71	20	9	14
2634	18	13	2.0	64	27	9	12
2633	21	13	2.2	57	33	10	13
2632	15	16	2.0	49	38	13	10
2631	14	18	1.8	47	39	14	9
2630	14	11	2.2	48	40	12	7
2629	14	18	2.2	52	37	11	6
2628	15	20	2.0	48	39	13	6
2627	12	19	1.9	46	40	14	7
2626	14	14	1.2	64	24	12	12
NORTH QUINCY SECTION (Frye, Glass, and Willman, 1962)							
P-1223	—	10	0.7	82	9	9	26
1222	—	20	0.6	79	10	11	22
1221	25	21	1.0	72	17	11	17
1220	10	20	1.1	73	17	10	18

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
NORTH QUINCY SECTION Cont. (Frye, Glass, and Willman, 1962)							
P-1219	27	22	1.3	71	18	11	16
1218	7	25	1.4	76	16	8	25
1217	—	10	1.2	76	15	9	27
1216	—	5	0.9	78	13	9	24
1215	—	—	0.8	73	14	13	20
1214	—	—	0.4	62	15	23	
PARTRIDGE CREEK SECTION							
P-1560	—	—	*	*	*	*	14
1559	—	—	1.2	71	19	10	15
1558	—	8	2.2	58	32	10	13
1557	—	11	2.3	57	32	11	10
1556	—	9	2.6	54	36	10	13
1555	5	13	3.2	43	47	10	10
1554	—	15	2.4	55	35	10	13
1553	—	15	1.5	63	27	10	13
1552	—	18	1.5	64	26	10	10
1551	5	17	1.6	67	23	10	17
1550	3	15	1.8	66	25	9	19
1549	7	15	2.0	60	30	10	13
1548	10	38	3.0	22	64	14	
1547	40	36	3.7	18	70	12	
1546	22	26	4.0	17	71	12	
PEKIN SOUTH SECTION							
P-2715	—	—	*	*	*	*	3
2714	—	—	*	*	*	*	11
2713	—	—	2.1	57	33	10	12
2712	—	—	2.3	64	28	8	18
2711	—	17	3.4	43	47	10	6
2710	11	17	1.5	60	28	12	10
2709	—	8	1.7	61	28	11	9
2708	—	—	0.9	82	10	8	23
2707	—	—	0.9	82	10	8	29
2706	—	—	0.8	86	8	6	33
2705	—	—	0.7	87	7	6	31
2704	—	—	0.9	86	8	6	32
2703	—	—	0.8	80	11	9	28
2702	—	—	0.6	84	7	9	
2701	—	—	0.6	78	10	12	
2700	—	—	0.6	80	9	11	
2699	—	—	0.6	82	8	10	

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
PEKIN SOUTH SECTION Cont.							
P-2698	—	—	0.7	80	10	10	
2697	—	—	0.6	81	8	11	
2696	—	—	0.6	69	14	17	
2695	—	—	0.6	77	10	13	
2694	—	—	0.6	80	9	11	
PERRY EAST SECTION (Frye and Willman, 1965)							
P-1953	—	—	2.3	60	31	9	14
1952	—	—	1.8	71	21	8	18
1951	—	—	0.8	71	16	13	15
1950	—	—	0.7	69	16	15	16
1949	—	12	0.8	75	13	12	17
1948	—	25	0.8	75	13	12	16
1947	—	—	0.5	59	17	24	
RAPID CITY (B) SECTION							
P-2361	—	—	*	*	*	*	10
2360	—	—	*	*	*	*	13
2359	—	5	1.4	72	19	9	11
2358	—	19	1.5	71	20	9	15
2357	—	22	1.2	73	18	9	17
2356	—	19	1.2	75	16	9	20
2355	—	10	1.1	70	19	11	16
2354	6	10	0.8	73	15	12	19
2353	12	15	1.3	66	22	12	15
2352	28	13	1.0	82	11	7	27
2351	—	—	0.5	77	9	14	
2453	12	18	1.2	68	21	11	17
2452	14	18	1.2	67	21	12	13
2451	9	29	1.2	69	20	11	14
2450	9	16	0.7	80	10	10	25
2449	—	—	0.7	83	9	8	29
2448	—	—	0.4	74	9	17	
2447	—	—	0.3	74	8	18	
2446	—	—	0.4	71	11	18	
2445	—	—	—	87	—	13	
2444	—	—	0.2	80	4	16	
2443	—	—	0.3	77	8	16	
2442	—	—	0.4	24	30	46	
2441	—	—	1.0	18	49	33	
2440	—	—	1.4	14	58	28	

TABLE 1 — CONTINUED

Sample no.	Counts per second: Calcite	Counts per second: Dolomite	D. I. ratio†	Percent of clay mineral: Expandable clay minerals	Percent of clay mineral: Illite	Percent of clay mineral: Kaolinite plus chlorite	Heterogeneous swelling index
RAPID CITY (B) SECTION Cont.							
P-2439	—	—					
2438	—	13	0.9	31	41	28	
2437	—	25	0.9	35	38	27	
2436	14	25	0.9	37	37	26	
2435	—	24	1.1	33	41	26	
2433	12	27	1.2	37	41	22	
2432	22	30	1.0	36	39	25	
2431	15	25	1.3	28	48	24	
2430	19	32	1.0	35	39	26	
RICHLAND CREEK SECTION (Glass, Frye, and Willman, 1964)							
P- 566	20	105		6	64	30	
1354	14	280	1.2	41	37	22	9
1353	38	265	1.1	41	36	23	9
1352	58	185	1.2	43	34	23	9
1351	18	90	1.1	49	32	19	13
1350	—	220	0.9	62	21	17	15
1349	5	185	1.0	62	22	16	16
1348	10	135	1.1	61	24	15	13
1347	—	200	1.0	60	24	16	16
1346	—	125	1.1	61	25	14	16
1345	—	240	1.1	61	25	14	12
1344	6	100	1.0	64	22	14	16
1343	—	150	0.9	64	21	15	19
RUSHVILLE (0.4W) SECTION (Frye and Willman, 1960)							
P- 673	—	—	*	*	*	*	2
672	—	—	2.3	66	26	8	10
671	—	—	2.2	68	25	7	10
670	—	11	2.0	55	34	11	8
669	—	11	2.0	62	28	10	7
668	—	10	1.6	65	25	10	10
667	—	12	1.3	64	24	12	9
666	—	11	1.0	56	26	18	10
665	—	17	0.7	62	20	18	11
664	—	8	0.8	65	19	16	13
663	—	15	0.7	71	15	14	12
626A	—	—	0.4	72	11	17	
SEPO SECTION (Frye, Glass and Willman, 1962)							
P- 884	—	—	*	*	*	*	4
883	—	—	1.9	66	25	9	8

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
SEPO SECTION Cont.							
P- 882	—	—	1.8	62	27	11	5
881	—	—	1.9	63	27	10	7
880	—	11	2.1	60	30	10	7
879	—	21	2.2	42	45	13	3
878	—	22	2.6	48	41	11	7
877	—	21	1.9	56	33	11	6
876	—	17	1.5	63	26	11	9
875	—	10	0.9	69	18	13	12
874	—	11	0.9	66	20	14	12
873	—	12	0.8	70	17	13	12
872	—	10	0.9	71	17	12	20
871	—	14	0.9	68	19	13	19
870	—	20	0.9	74	15	11	22
869	—	11	1.0	70	18	12	20
868	—	12	1.1	70	19	11	18
867	—	11	1.1	69	20	11	20
866	—	12	0.8	63	20	17	15
865	—	—	0.4	64	14	22	
SISTER CREEK SECTION (Gore, 1952)							
P-2154	—	—	*	*	*	*	4
2153	—	—	*	*	*	*	5
2152	—	—	*	*	*	*	7
2151	—	10	2.2	63	28	9	16
2150	—	11	2.1	64	27	9	12
2149	—	10	2.3	47	41	12	6
2148	—	9	2.4	42	45	13	7
2147	—	18	2.1	47	40	13	6
2146	—	12	2.8	32	55	13	6
2145	—	21	3.0	27	60	13	3
2144	—	12	2.5	35	52	13	3
2143	—	14	3.3	26	61	13	0
2142	—	13	1.4	54	31	15	8
2141	—	8	1.3	54	31	15	9
2140	—	6	1.3	65	23	12	11
2139	—	10	1.1	59	26	15	10
2138	—	10	1.4	65	23	12	9
2137	—	17	1.0	55	27	18	11
2136	—	3	1.3	65	23	12	11
2135	—	5	1.4	67	22	11	11
2134	—	10	1.2	68	21	11	15
2133	—	9	1.3	55	30	15	8
2132	—	8	1.2	63	24	13	8
2131	—	—	0.6	70	14	16	
2130	—	—	0.6	71	14	15	

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
STUDYVIN SCHOOL SECTION							
P-2743X	—	—	*	*	*	*	3
2742X	—	—	*	*	*	*	9
2741X	—	—	*	*	*	*	8
2740X	—	—	*	*	*	*	8
2739X	—	—	*	*	*	*	10
2738X	—	—	*	*	*	*	13
2737X	—	—	*	*	*	*	14
2736X	—	—	3.0	62	31	7	14
2735X	—	11	2.5	49	40	11	8
2734X	—	10	3.0	43	46	11	8
2733X	—	10	2.4	46	42	12	8
2732X	—	15	3.0	48	42	10	5
2731X	—	10	3.0	47	43	10	6
2730X	—	14	2.4	48	41	11	5
2729X	8	19	4.4	33	58	9	
2728X	13	22	4.9	22	68	10	
2727X	12	25	4.6	22	68	10	
2726X	—	8	1.1	70	19	11	
10-MILE SCHOOL SECTION							
P-1578	—	17	2.1	66	26	8	17
1577	—	10	2.2	65	27	8	12
1576	—	12	2.1	61	30	9	15
1575	12	17	2.3	63	28	9	18
1574	13	16	2.2	63	27	10	16
1573	17	25	2.3	57	34	9	15
1572	14	14	2.8	46	44	10	7
1571	8	12	1.6	66	24	10	16
1570	—	20	1.3	70	20	10	21
1569	—	15	1.4	72	19	9	20
1568	—	16	1.5	72	19	9	21
1567	5	12	1.5	73	19	8	21
1566	—	18	1.6	70	21	9	20
1565	12	35	3.1	52	40	8	9
1564	25	45	4.9	19	71	10	
VARNA SOUTH SECTION							
P-2693	—	—	*	*	*	*	0
2692	—	—	*	*	*	*	2
2691	—	—	*	*	*	*	12
2690	—	—	0.9	81	10	9	20
2689	—	—	0.9	77	13	10	19

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
VARNA SOUTH SECTION Cont.							
P-2688	—	—	1.1	79	13	8	22
2687	—	9	1.2	72	18	10	18
2686	—	15	1.4	67	23	10	17
2685	—	15	1.3	68	22	10	16
2684	—	13	2.0	54	35	11	11
2683	—	20	2.3	53	36	11	12
2682	7	9	3.9	3	83	14	
1993	—	—	1.1	76	15	9	15
1992	—	—	1.7	68	23	9	15
1991	10	35	1.5	61	27	12	14
1990	—	28	1.4	59	28	13	13
1989	—	37	1.9	53	34	13	11
1988	—	30	1.4	63	25	12	14
1987	13	27	2.3	37	49	14	8
1986	9	40	2.1	48	40	12	10
1985	10	17	4.7	3	85	12	
WALNUT SE SECTION							
P-2438A	—	—	1.0	84	10	6	28
2437A	—	10	1.0	81	12	7	30
2436A	—	10	1.2	81	12	7	33
2435A	—	10	1.2	81	12	7	29
2434A	10	14	1.3	80	13	7	30
2433A	15	17	1.2	76	15	9	24
2432A	13	20	1.4	74	17	9	27
2431A	13	27	1.5	74	18	8	26
2430A	8	17	1.8	68	23	9	19
2429	—	20	1.7	67	24	9	21
2428	—	25	1.7	63	27	10	13
2427	—	25	1.5	63	26	11	12
2426	7	19	2.2	55	34	11	10
2425	21	37	2.8	21	64	15	
WANLOCK SECTION							
P-2332	—	—	*	*	*	*	16
2331	—	—	0.9	71	17	12	21
2330	—	—	1.0	71	17	12	22
2329	—	—	0.8	66	18	16	19
2328	—	—	0.6	72	13	15	22
2327	—	—	0.6	74	13	13	22
2326	—	9	0.8	72	15	13	22
2325	—	17	1.0	74	16	10	17

TABLE 1 — CONTINUED

Sample no.	Counts per second		D. I. ratio†	Percent of clay mineral			Heterogeneous swelling index
	Calcite	Dolomite		Expandable clay minerals	Illite	Kaolinite plus chlorite	
WANLOCK SECTION Cont.							
P-2324	—	17	0.7	77	12	11	21
2323	—	—	0.6	74	13	13	17
2322	—	—	0.4	71	10	19	
2321	—	—	0.4	58	15	27	
2320	—	—	0.3	52	16	32	
2319	—	—	0.4	37	25	38	

†Diffraction intensity ratio = counts per second for illite (10Å) divided by counts per second for kaolinite plus chlorite (7.2Å).

*Weathered material in soil profile; not calculated.

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