Definition of Wisconsinan Stage

By JOHN C. FRYE, H. B. WILLMAN, MEYER RUBIN, *and* ROBERT F. BLACK

CONTRIBUTIONS TO STRATIGRAPHY

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The Wisconsinan Stage and its Altonian, Farmdalian, Woodfordian, Twocreekan, and Valderan Substages are described as time-stratigraphic units of the Pleistocene of Illinois and Wisconsin

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DEFINITION OF WISCONSINAN STAGE

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Abstract

The Wisconsinan Stage of the Pleistocene is described and defined as a time-stratigraphic unit for use in Illinois and Wisconsin. The Wisconsinan includes all deposits from the contact of the Roxana Silt on the A-horizon of the Sangamon soil at the base to the top of the Cochrane till and its contact with the overlying post-Cochrane deposits in the James Bay Lowland of Ontario, Canada. The substages of the Wisconsinan Stage also are described and defined; these are (from the base upward) the Altonian, Farmdalian, Woodfordian, Twocreekan, and Valderan. Correlations from type areas throughout this region are based on physical stratigraphy, abundant radiocarbon age determinations, and paleontology.

INTRODUCTION

It is our intent herein to clarify the definition of the Wisconsinan Stage, in keeping with the prescribed procedures of the Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1961), for use in Illinois and Wisconsin. Correlations from type areas throughout this region are based on physical stratigraphy, abundant radiocarbon age determinations, and paleontology. The adoption of Wisconsinan Stage by the U.S. Geological Survey represents the Survey's first usage of stage as a time-stratigraphic term in the Pleistocene.

WISCONSINAN STAGE

We here define the Wisconsinan Stage to include all deposits from the contact of Roxana Silt on the A-horizon of the Sangamon soil to the top of the Cochrane till and its contact with the overlying thin discontinuous post-Cochrane deposits in the James Bay Lowland of Ontario, Canada. As thus defined, the Wisconsinan Stage includes (in successive order upward) the Altonian, Farmdalian, Woodfordian, Twocreekan, and Valderan Substages; the

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deposits and limits of each substage will be described. Geographic locations of described geologic reference sections and type localities of substages are shown in figure 1.

FIGURE 1.—Locations of type localities of the Wisconsinan substages and geologic reference sections described in this report.

HISTORICAL REVIEW

The term Wisconsinan Stage has evolved from the term "East-Wisconsin formation," which was used by T. C. Chamberlin (1894). Chamberlin's original description (p. 763) was in part,

> Overlapping the preceding formation there comes a very complex sheet of drift, characterized by much more pronounced glacial features, along which are massive terminal moraines, not only defining the outer edge of the sheet, but marking various stages of its development, some of which are connected with imbricating overlaps. For present convenience, all this complex is grouped under a single term—the East-Wisconsin formation—because the grounds for a formal subdivision are not yet clear. Eastern Wisconsin is selected as the denominative locality because the formation there takes on a very pronounced development and assumes some of its most striking characteristics.
>
> * * * In Illinois, Indiana and Ohio the outermost moraines, together with one to five of the succeeding ones, constitute a group somewhat distinctly separable from a later group, which embraces from five to seven or more successive terminal moraines.

Chamberlin further stated (1894, p. 764),

> A very notable feature of the East-Wisconsin formation is presented by the loops of its terminal moraines, which indicate strong lobation of the ice-sheet * * *. The accompanying map presents to the eye something of the extent and nature of this lobation * * *

The differentiation of a younger glacial drift, the "Second Glacial Epoch," in the drift-covered region of the Central States resulted from recognition that the "Kettle Range" in Wisconsin represented a terminal moraine of the Green Bay and Lake Michigan glaciers (Chamberlin, 1877, 1878, 1883). Chamberlin placed the boundary of the younger drift in Illinois approximately at the Minooka moraine (1878), but later placed it nearer the Valparaiso moraine (1883). By the time he introduced the "East-Wisconsin" in 1894 (fig. 2), the area of the younger drift had been extended to the margin of the Shelbyville moraine in central and eastern Illinois, and the drift was considered to be divisible into two units at the front of the Valparaiso moraine. The "pre-East-Wisconsin" unit was differentiated into an "East-Iowan" drift and a "Kansas drift" (older), and the "East-Wisconsin" unit became the third glacial epoch.

Concerning the boundary below his East-Wisconsin formation, Chamberlin stated (1894, p. 762):

> Between the East-Iowan formation and the overlapping sheet of till, presently to be described, occurs a second horizon marked by soils, vegetal accumulations, oxidation, ferrugination, erosion, and other indications of a

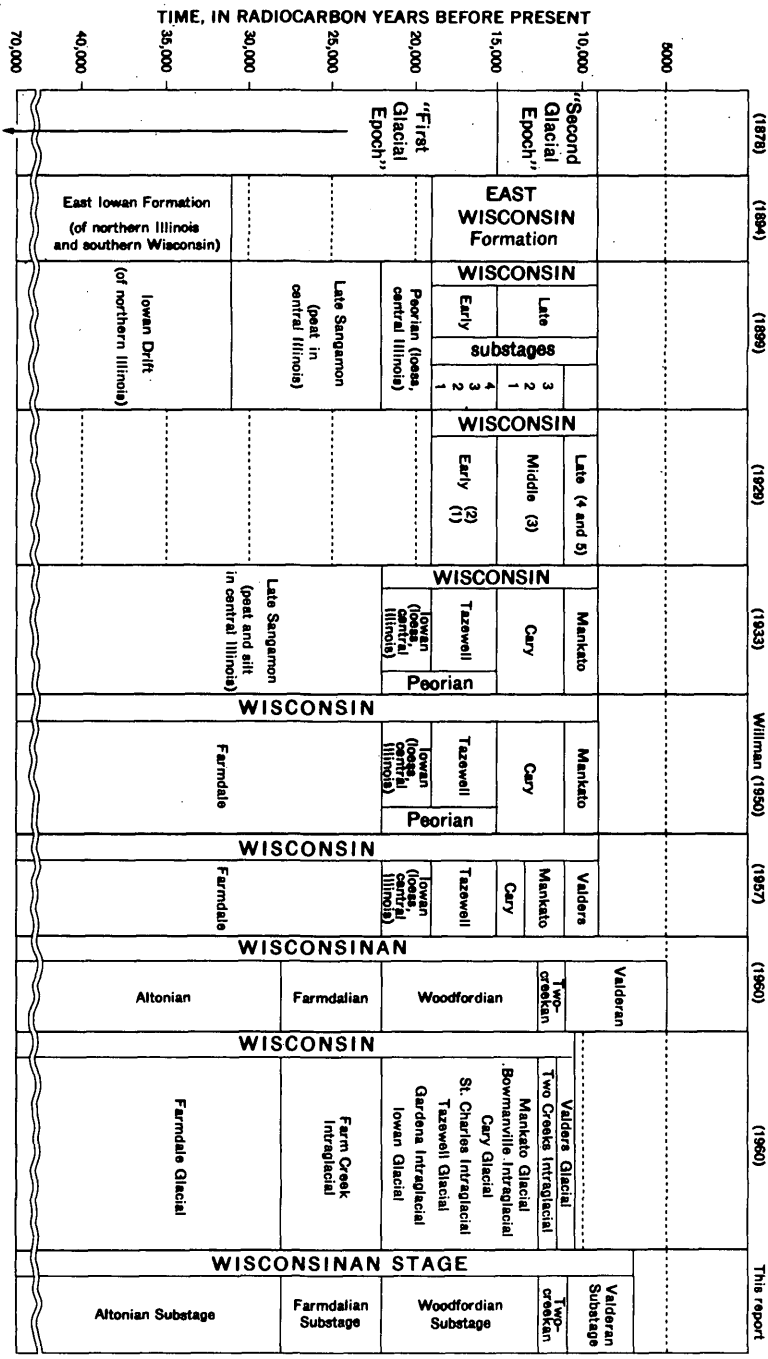
TIME, IN RADIOCARBON YEARS BEFORE PRESENT
70,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
8000
Chamberlin (1878)
Chamberlin (1894)
Leverett (1899)
Leverett (1929)
Leighton (1933)
Leighton and Willman (1950)
Leighton (1957)
Frye and Willman (1960)
Leighton (1960)
This report
"First Glacial Epoch"
"Second Glacial Epoch"
East Iowan Formation (of northern Illinois and southern Wisconsin)
Iowan Drift (of northern Illinois)
Late Sangamon (peat in central Illinois)
Peorian (loess, central Illinois)
EAST WISCONSIN Formation
WISCONSIN
Early
Late
substages
4 3 2 1
3 2 1
Early (2) (1)
Middle (3)
Late (4 and 5)
Iowan (loess, central Illinois)
Tazewell
Cary
Mankato
Peorian
Late Sangamon (peat and silt in central Illinois)
Farmdale
Valderan
Mankato
Cary
Tazewell
Iowan (loess, central Illinois)
WISCONSINAN
Altonian
Farmdalian
Woodfordian
Two-creekan
Valderan
Farmdale Glacial
Farm Creek Intraglacial
Valders Glacial
Two Creeks Intraglacial
Mankato Glacial
Bowmanville Intraglacial
Cary Glacial
St. Charles Intraglacial
Tazewell Glacial
Gardena Intraglacial
Iowan Glacial
WISCONSINAN STAGE
Altonian Substage
Farmdalian Substage
Woodfordian Substage
Two-creekan
Valderan Substage

FIGURE 2.—Evolution of the time-stratigraphic classification of the Wisconsinan Stage in the type region. The units are placed in a framework of radiocarbon ages on the basis of the dates that are now available from the region. It should be pointed out that in 1899 it was not known that the peats in central Illinois called "Late Sangamon" (Farmdalian of present classification) were younger than the drift in northern Illinois called "Iowan" (Altonian of present classification), nor was it known in 1933 that the "Iowan" loess in central Illinois (Morton Loess of present classification) was younger than any of the drifts classed as "Iowan."

notable interval. These are not traceable so far back beneath the upper formation as in the preceding instance * * *. Nevertheless, even under great depths of morainic debris, soils, beds of peat, and remains of trees are found at many localities. The interval, however, is best shown by the marked differences between the erosion of the preceding and succeeding surfaces.

It seems clear that in the southern Wisconsin and northern Illinois region, with which he was concerned, Chamberlin was referring primarily to the widespread peats that have since been widely recognized, radiocarbon dated, and placed in the unit now called Farmdale. This conclusion is supported by the fact that the till he called "East-Iowan" adjacent to the Illinois-Wisconsin State line has been radiocarbon dated as Altonian in age; the Altonian is the unit just below the Farmdale.

Later, Chamberlin (1895, p. 275) changed his East-Wisconsin formation to Wisconsin formation.

Leverett (1899, p. 191–417) gave the first comprehensive description of the Wisconsin drift sheets in Illinois. By this time, Leverett had described the Illinoian glacial stage, and its overlying Sangamon soil, as underlying the deposits now classed as Wisconsinan (East-Iowan plus Wisconsin of Chamberlin) and, in southeastern Iowa, overlying the Kansan drift. Leverett stated (1899, p. 191):

The northeastern fourth of Illinois and adjacent portions of Indiana are covered by a sheet of drift, somewhat fresher than the Iowan, which has its terminus in the Shelbyville moraine, but which embraces several morainic systems of considerable prominence that lie between the Shelbyville moraine and the border of Lake Michigan. The term "early Wisconsin" is restricted to the moraines which lie outside the bulky moraine that encircles the head of the lake * * *. The moraines included in the late Wisconsin are not concentric with the earlier group * * *. In Illinois the early Wisconsin is well exposed outside the late Wisconsin series, probably better than in any other part of the glaciated district.

Concerning the base of the Wisconsin drift, Leverett (1899, p. 141) stated:

The Wisconsin drift may usually be readily separated from the older sheets which underlie it. Its uniform blue color and the ease with which it may be penetrated by auger or spade enable the well drillers to distinguish it readily from the underlying deposits, which are brown or gray color and more difficult to penetrate. There is also in many places a black soil at the junction of this sheet with the underlying drift which furnished additional evidence of the passage from the Wisconsin to an older drift * * *. There is often considerable peat at this lower soil horizon * * *.

It is, of course, now impossible to reexamine the well sections Leverett cited as evidence for the above statements. However,

several dozen core holes that have penetrated a similar sequence within Illinois and more than a dozen radiocarbon dates on peat and wood from the same stratigraphic position within core samples and outcrop sections seem to leave little doubt that the black soil and peat are the unit now called Farmdale Silt. Leverett therefore probably intended to exclude from the Wisconsin those deposits now classed as the Farmdalian and Altonian Substages. His intent on this point is not clear, however, because in central Illinois, he assigned the loess (Morton Loess of the present classification) above the peaty zone (Farmdale Silt) and below the Shelbyville till to the "Iowan" glaciation.

Leighton (1931) included the "Iowan" in the Wisconsin glacial stage and thus redefined the base of the Wisconsin in Illinois by including the "Iowan" loess (Morton Loess) within it.

The lower boundary of the Wisconsin was later modified again by the inclusion of the Farmdale Silt (named by Leighton in a footnote in Wascher and others, 1948, p. 300) as the earliest substage of the Wisconsin. Leighton and Willman (1950) regarded the Farmdale as pro-Wisconsin and described it as follows (p. 602):

> A silt deposit which lies on the weathered zone and erosional slopes of the Illinoian drift and which has a very youthful profile of weathering beneath the Peorian loess was recognized as loess by Leighton in 1920 and described in a publication by him in 1926. He called it "Late Sangamon loess" but later renamed it "Farmdale" from the exposures in the Farm Creek section, near Farmdale, Tazewell County, Illinois * * * [p. 603]. This, in turn, implies an extension of an ice sheet during the Farmdale substage into the drainage basin of the ancestral Mississippi prior to the Iowan substage but not yet recognized in the series of drift sheets because it fell short of subsequent ice lobes.

Immediately following the introduction of the term, Farmdale was extended westward into the Great Plains (Frye and Leonard, 1951, 1952) and, in the loess sequence, was generally accepted as representing the basal unit of the Wisconsinan Stage.

Contradictory evidence as to the age and correlation of the base of the Wisconsinan, however, was introduced by radiocarbon dating of the "Iowan" in Iowa and Illinois. In Illinois the term "Iowan" had been applied to a loess (Morton Loess of present classification) for which a radiocarbon age of 19,500–22,000 years B.P. (before present) has been firmly established. This loess occurs stratigraphically below the Shelbyville till and above the Farmdale Silt. To date, 21 radiocarbon age determinations have been made from the Farmdale deposits of Illinois; these ages

range from 22,450±1,000 (W–334 and I–2518 [3]) to 27,200+1,000–900 (I–2220). In eastern Iowa on the other hand, radiocarbon dates (greater than 34,000 (W–534) to greater than 38,000 (W–139)) indicated that "type-Iowan" till was significantly older than the Farmdale Silt (Ruhe and others, 1957). Because of this difference in the radiocarbon dates and because of the desirability to base the classification on the continuous sequence of deposits in the Lake Michigan Lobe, the term "Iowan" was dropped from the classification of the Illinois State Geological Survey (Frye and Willman, 1960). The confusion concerning the placement of the "Iowan" has been resolved by Ruhe and others (Friends of the Pleistocene [Midwest Group], 16th Annual Meeting, 1965), who demonstrated that "Iowan" till in the type area is actually eroded Kansan till and therefore cannot be correlated with the so-called "Iowan" of Illinois.

Shaffer (1956) studied the drift in central-northern Illinois, including that called "Iowan" by Chamberlin and by Leverett prior to 1900, but which was subsequently assigned to the Illinoian by Alden (1918). Shaffer concluded that much of the drift of the area was older than Shelbyville but younger than Illinoian, a relationship suggested by Leverett (1899), and Shaffer therefore assigned the drift to the Farmdale, which was at that time considered the earliest Wisconsin glacial substage. Shortly thereafter, Black (1958) reported a radiocarbon date of 31,800±1,200 (W–628) from comparable till in southern Wisconsin, and Kempton (1963, 1966) reported additional radiocarbon dates from central-northern Illinois. To date, eight finite and 12 off-scale radiocarbon age determinations have been made on materials from Altonian deposits in Illinois, and six finite and four off-scale radiocarbon determinations have been made on Altonian deposits from Wisconsin.

Acting on Moore's (1947) recommendation to the American Commission on Stratigraphic Nomenclature, Frye, Swineford, and Leonard (1948) applied the adjectival ending to Wisconsinan Stage to identify it as a time-stratigraphic unit.

From the foregoing historical review, it is apparent that the base of the Wisconsinan has been revised downward from the base of the Valparaiso drift, to the base of the Shelbyville drift,

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[3] Radiocarbon samples throughout paper are numbered with a prefix denoting the laboratory in which they were analyzed: W, U.S. Geological Survey; I, Isotopes, Inc.; GrN, Groningen, Netherlands. The ages are given in years B.P. (before present); "present" is arbitrarily chosen as A.D. 1950.

to the base of the Morton Loess (then called "Iowan"), and finally to the base of the Roxana Silt (formerly included within the Farmdale).

DEPOSITS AND AGE

At present, the base of the Wisconsinan Stage is defined as the contact of Roxana Silt on the A-horizon of the Sangamon soil. Beyond the limit of Wisconsinan glaciers in Illinois, the relation is well shown in many geologic reference sections. Within the Pleasant Grove School section (given below), which contains the type section of Roxana Silt (Frye and Willman, 1960, p. 10; Schultz and Smith, 1965b, p. 13), the Sangamon soil is developed in thin Loveland Silt and also laterally in till of Illinoian age; within the Cottonwood School section (Leonard and Frye, 1960, p. 27) given below, the Sangamon soil is developed in till. Much of the Wisconsinan Stage is represented in the above listed reference sections and adjacent described sections (for example, French Village and Collinsville sections, Frye and others, 1962); fossil molluscan faunas have been described from several faunal zones within these sections (Leonard and Frye, 1960). Radiocarbon dates on both wood and snail shells from these sections in Illinois demonstrate contemporaneity with the larger number of radiocarbon dates on wood and peat intercalated within the sequence of the glacial tills northward in Illinois and Wisconsin.

Reference section of Pleistocene deposits at Pleasant Grove School, including the type section of Roxana Silt

[Measured in nearly vertical face of large pit for earthfill material in center SE ¼ sec. 20, T. 3 N., R. 8 W., Madison County, Ill. The uppermost 25 feet was measured in excavations above the main pit and about 50 yards to the northeast]

	Thickness (ft)
Pleistocene Series:	
Wisconsinan Stage:	
Woodfordian Substage:	
Peoria Loess:	
9. Loess, medium to coarse; loose and friable in upper part; calcareous except in very thin surface soil at top; light yellow tan including some streaks and mottling of tan brown and gray; contains several very weakly developed A-horizons in upper part	25.0
8. Loess, medium to coarse, massive, compact, calcareous, gray-tan to yellow-tan; contains fossil snail shells throughout (Leonard and Frye, 1960); radiocarbon date from one-fourth mile south, 17,950±550 (W–1055), determined on wood; radiocarbon data from 1 mile north, 17,100±300 (W–730), determined on fossil snail shells	15.0

Reference section of Pleistocene deposits at Pleasant Grove School, including the type section of Roxana Silt—Continued

	Thickness (ft)
Pleistocene Series—Continued	
Wisconsinan Stage—Continued	
Altonian Substage:	
Roxana Silt:	
7. Loess, medium to coarse, massive, pink-tan, non-fossiliferous; leached in part but weakly calcareous in lower part; sharp erosional contact at top, but gradational at base	11.0
6. Loess, medium to coarse, massive, gray-tan to gray; weakly calcareous throughout; contains fossil snail shells in lower part	12.0
5. Loess, coarse, massive, pink-tan, calcareous; contains fossil snail shells throughout (Leonard and Frye, 1960); radiocarbon date on shells from upper part of this zone, 35,200±1,000 (W–729); when the face was exposed in the pit, a zone of fine sand was seen in the middle of this bed	20.0
4. Silt, coarse, massive, gray; leached in upper part, but weakly calcareous in lower part where bed has maximum thickness; locally contains a humic A-horizon at top, but a well-developed B-horizon was not observed	5.0
Sangamonian and Illinoian Stages of Frye, Willman, and Black (1965):	
3. Sangamon soil; developed in silt, coarse, massive, noncalcareous; A-horizon, tan-brown, granular, three-fourths-foot thick, grading downward to B_2-horizon, red-brown, clayey, columnar structured, 2-foot thick; B_3-horizon and C-horizon, friable, tan to light-brown, gradational downward	3.5
2. Silt, massive, gray to gray-tan; contains streaks of yellow brown; leached; at north end of exposure this unit is 15 feet thick and is calcareous in the lower part. (This silt is judged to be equivalent to the Roby Silt, Buffalo Hart Substage of Frye, Willman, and Black (1965) of central Illinois.)	7.0
Illinoian Stage of Frye, Willman, and Black (1965):	
Liman Substage of Frye, Willman, and Black (1965):	
1. Till, having truncated soil at top; weakly developed B-horizon exposed only at the highest point on the erosional contact surface, leached in upper part and calcareous in lower part. At the erosional contact between beds 1 and 2 at the north end of the pit, calcareous silt overlies calcareous till	11.5
Total thickness of Pleistocene deposits	110.0

Reference section of Pleistocene deposits at Cottonwood School

[Measured in roadcuts on the valley bluff at center of east border, sec. 11, T. 18 N., R. 11 W., Cass County, Ill.]

	Thickness (ft)
Pleistocene Series:	
Wisconsinan Stage:	
Woodfordian Substage:	
Peoria Loess:	
9. Loess, coarse, gray-tan to pale-yellow-tan; massive to indistinctly bedded and laminated; calcareous except in thin surface soil at top; sparsely fossiliferous in lower and middle part; contains two weakly developed A–C soil profiles in upper part	25.0
8. Loess, coarse to medium, gray-tan, massive, calcareous; indistinct streaks of pale pink throughout; contains fossil snails listed in Leonard and Frye (1960)	15.0
Altonian Substage:	
Roxana Silt:	
7. Loess, coarse, massive; dark pink in lower part grading upward to pink gray; leached in upper part to weakly calcareous in lower part; contains a few snail shells except in uppermost part; sharp contact at top suggests erosional truncation	15.0
6. Loess, medium, neutral-gray, massive, weakly calcareous; contains limonite tubules throughout	10.0
5. Loess, medium, pink-tan, massive, weakly calcareous, nonfossiliferous; sharp contact at base, but gradational with bed above; contains limonite tubules and small calcium carbonate concretions throughout	8.0
4. Silt containing some sand and dispersed small chert pebbles in lower part; gray with some tan mottling; leached; the fabric of the deposit and presence of angular chert fragments and clay pellets suggesting derivation from the underlying Sangamon soil indicate that the lower part of the deposit is colluvium	5.0
Sangamonian and Illinoian Stages of Frye, Willman, and Black (1965):	
3. Sangamon soil developed in till; contains pebbles and cobbles; grades downward into calcareous, gray, compact till; soil profile in upper part has an A-horizon, thin, brown, gradational with a B-horizon, red-brown, clayey, about 2 feet thick	8.0
2. Silt, gray- and tan-banded, compact, blocky, calcareous; contains some sand and a few small pebbles	3.0
1. Till, gray to gray-brown, massive, compact, calcareous, pebbly; rests on shale and siltstone of Pennsylvanian age	5.0
Total thickness of Pleistocene deposits	94.0

At the southern extremity of Wisconsinan glaciers, the younger Woodfordian glaciers considerably overlapped the earlier Altonian glaciers; therefore, here also the basal Wisconsinan deposit on Sangamon soil is Roxana Silt (for example, Richland Creek and Varna sections, Frye and others, 1962, p. 54–55). Radiocarbon dates have been obtained from peat and wood in the Farmdale Silt that overlies the Roxana Silt in several such sections (for example, Danvers section, Frye and others, 1962, p. 50).

In extreme northern Illinois, the pre-Farmdale (Altonian) part of the Wisconsinan Stage is represented by glacial tills interbedded with silt, sand, and peat. In Wisconsin only the youngest pre-Farmdale till has been studied (Black, 1958, 1959, 1962; Black and others, in Schultz and Smith, 1965a, p. 56–81), and in northeastern Illinois detailed data from the older units are derived primarily from a series of core borings that penetrated to a depth of as much as 400 feet (Kempton, 1963, 1966; Kempton and Hackett, 1963). Radiocarbon dates have been obtained on peat between tills from several of these cores, but attempts to date the lowest peats in the Wisconsinan sequence have been futile because they are too old for the method currently used.

Although essentially all the Wisconsinan Stage is represented in the loess sequence above Illinoian till, most exposures within the area of Wisconsinan glacial deposits contain only a small fraction of the sequence (note the Wedron section in this report), and the type area of the Wisconsinan Stage must include sections occurring through several hundred miles from central Illinois to the Door Peninsula of Wisconsin. However, the stratigraphic relations of the glacial sequence to the loess sequence can now be demonstrated by physical stratigraphy, and, except for the earliest part of the Wisconsinan, by more than 100 radiocarbon dates in Illinois and Wisconsin.

The upper boundary of the Wisconsinan Stage is defined with less precision than the lower boundary. In recent years this upper boundary has been placed at several different stratigraphic positions by various workers. Frye and Willman (1960) used a radiocarbon date of 5,000 B.P. as the end of the Wisconsinan on the basis that this date represents the approximate return of sea level to its present position following the final dissipation of a continental ice cap from the interior of the continent. The return of sea level, however, has been interpreted to have taken place as recently as 3,500 years B.P. As a boundary of this type cannot be defined in a stratigraphic sequence in compliance with the

Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1961), we now define the upper boundary of the Wisconsinan Stage as the contact between the Cochrane till and the post-Cochrane deposits in the Ontario, Canada, region (Karlstrom and Rubin, 1955; Karlstrom, 1956; Hughes, 1956, p. 5). The stratigraphic sequence and dating of the deposits have been described (Terasmae and Hughes, 1960a, 1960b; Hughes, 1965), and withdrawal of the ice from the Cochrane moraine is dated at approximately 7,000 radiocarbon years B.P.

SUBSTAGES OF WISCONSINAN STAGE

Chamberlin (1894), Leverett (1899), and Alden (1918) considered their Wisconsin stage (Shelbyville and younger) to be divisible into two substages (fig. 2) at the front of the Johnstown and Valparaiso moraines. Leverett (1929) introduced early, middle, and late subdivisions by dividing the pre-Valparaiso drift at the front of the Bloomington moraine. Leighton (1931) introduced Hudsonian substage for the late Wisconsin, Quebecan substage for the early and middle Wisconsin, and Manitoban substage for his "Iowan." Leighton (1933) withdrew these three names and in their place proposed Mankato (late Wisconsin), Cary (middle Wisconsin), Tazewell (early Wisconsin), and "Iowan" (earliest Wisconsin). The classification was expanded to five substages by Leighton and Willman (1950) when they added the Farmdale as a substage next older than "Iowan" (fig. 2).

Thwaites (1943) proposed the name Valders for the youngest till in Wisconsin (his Wisconsin stage), that till lying above the Two Creeks forest bed (Goldthwait, 1907); he also proposed that the name be a replacement for Mankato in the Wisconsin region. Thwaites doubted, however, the contemporaneity of his Valders with the Mankato of northern Iowa and southern Minnesota, and his doubts have been amply justified by radiocarbon dates (Wright and Rubin, 1956; Ruhe and others, 1957). Subsequently, Leighton transposed the term Mankato, as used in Wisconsin and Illinois, from the Valders till above the Two Creeks deposits to the upper part of the Cary below the Two Creeks deposits, thus restricting the span of the Cary.

Frye and Willman (1960) proposed a new five-fold classification of the Wisconsinan Stage, introducing the Altonian (oldest), Farmdalian, Woodfordian, Twocreekan, and Valderan Substages. Shortly thereafter, Leighton (1960) modified his 1957 classifi-

cation to eleven units by recognizing Valders as the youngest unit, by applying the term Mankato to the upper part of the former Cary, by restricting the Cary, by placing the organic-rich silts of the typical Farmdale in the Farm Creek, by redefining Farmdale, and by recognizing Gardena, St. Charles, Bowmanville, and Two Creeks as interstadials (fig. 2).

It is our purpose here to review the definitions of the substages now in most common use in Wisconsin and Illinois (Frye and Willman, 1960; Frye and others, 1965).

ALTONIAN SUBSTAGE

The Altonian Substage was named for the city of Alton, Ill., and is defined on the basis of the Roxana Silt. The Roxana Silt is well exposed in the overburden of the abandoned quarry in the Mississippi River Bluffs at the north edge of Alton and in the Reliance Whiting Company quarry within the city limits (Frye and Willman, 1963, p. 17; Schultz and Smith, 1965b, p. 11). The Roxana also is well exposed at the Pleasant Grove School section (p. E10; Frye and Willman, 1960, p. 10), which is the type locality for the Roxana Silt. As previously described, the Roxana Silt rests on the top of the well-developed Sangamon soil and is bounded at the top by its contact with the organic-rich Farmdale Silt; in the absence of the Farmdale Silt, the top of the Roxana is bounded by a zone of leaching and soil formation or an eroded unconformable contact. The Roxana Silt is overlain by calcareous and fossiliferous Peoria Loess. The distinctive molluscan fauna from the upper units of the Roxana Silt has been described (Leonard and Frye, 1960). Radiocarbon dates from these fossiliferous upper units (35,200±1,000 (W–729) and 37,100±1,500 (W–869)) show an equivalence to dates obtained from peats between the tills below the Farmdale Silt in core borings and outcrops in northern Illinois: 32,600±520 (GrN–4408), 35,000±2,500 (W–1450), 38,000±3,000 (I–847), and 41,000±1,500 (GrN–4468). In southeastern Wisconsin, dates on spruce (31,800± 1,200 (W–638), 30,800±1,000 (W–901), 29,000±900 (W–903)) in till and outwash are slightly younger. These samples are interpreted as dating a short-lived ice advance immediately preceding the Farmdalian. These dates, together with abundant radiocarbon dates from the overlying Farmdale Silt, indicate that the age of the upper boundary of the Altonian Substage is 28,000 radiocarbon years B.P., or somewhat more. A radiometric date is not yet obtainable for the lower boundary of the substage; however, on the basis of the dates reported by Dreimanis,

Terasmae, and McKenzie (1966) from Ontario, Canada, an age of about 75,000 radiocarbon years B.P. seems reasonable.

The drift that Shaffer (1956) assigned to the Farmdale in northern Illinois is now included in the Altonian Substage, and the local rock-stratigraphic name, Winnebago drift, has been applied (Frye and Willman, 1960, p. 5). Black (1962) has proposed the term Rockian for the uppermost part of the Altonian Substage.

FARMDALIAN SUBSTAGE

The Farmdalian Substage is based on the Farmdale Silt, which is typically exposed near Farmdale, Tazewell County, Ill. (Frye and Willman, 1960, geol. section 2, p. 11; Frye and others, 1962, Danvers section, p. 50), where it consists of organic-rich silt and peaty silt overlying the Roxana Silt and overlain by calcareous fossiliferous Morton Loess. Within the Wedron section given below (see also Leonard and Frye, 1960, p. 31; Schultz and Smith, 1965a, p. 88, 89), the Farmdale Silt is a lacustrine deposit, from which an extensive fossil molluscan fauna has been described in association with two radiocarbon dates. In Illinois, 21 radiocarbon dates have been obtained from peat and wood in Farmdale Silt from outcrop sections and core borings. These dates range from 21,950±500 (I–2517) and 22,450±1,000 (W–334) to 26,800±700 (W–871) and 27,200+1,000–900 (I–2220). On the basis of these dates, it is considered reasonable to place the time span of the Farmdalian Substage, in radiocarbon years, from 22,000 B.P. to 28,000 B.P.

In its original description, the Farmdale Substage included all silt deposits overlying the Sangamon soil as high as, and including, the top of the organic-rich silts below the "Iowan" (Morton) loess. In the type area, however, most of this interval was occupied by organic-rich silts, from which radiocarbon dates in the range of 22,000 B.P.–27,200 B.P. were obtained, and only a few feet of organic-free loess separated these dated silts from the top of the Sangamon soil below. In contrast, along the lower Illinois and middle Mississippi River valleys, thick loess deposits that contain a leached zone at an erosionally truncated top occur below the calcareous fossiliferous Peoria Loess. On the basis of this relationship in the loess sequence, Frye and Willman (1960) restricted the term Farmdale to the organic-rich radiocarbon-dated silts at the type locality and defined the Roxana Silt as the thick unit of loess, silts, and sands that occur below the Farmdale and rest on the A-horizon of the Sangamon soil. Leighton (1960)

subsequently redefined the Farmdale, but chose the alternative of proposing a new name, Farm Creek, for the deposits of the original Farmdale type section in order to retain the name Farmdale for the glacial substage represented by the loess deposition.

WOODFORDIAN SUBSTAGE

The Woodfordian Substage was named for Woodford County, Ill. (Frye and Willman, 1960), and was defined as embracing the succession of rocks from the contact of Morton Loess on Farmdale Silt (note reference sections listed above) upward to the base of the Two Creeks deposits typically exposed in east-central Wisconsin. No soils, leached zones, or widely traceable key horizons occur within the Woodfordian sequence. Although no single exposure contains the entire succession of Woodfordian deposits, the Wedron section described below is representative of much of the substage. It is also the type section for the unit herein named the Wedron Formation. The upper boundary of the Woodfordian Substage is the contact of till with the water-laid silt, clay, and sand, including the forest bed (Thwaites and Bertrand, 1957, p. 856) typically exposed at Two Creeks, Wis. Beyond the limit of Woodfordian glaciation, the substage is well represented in sections of Peoria Loess along the bluffs of the Illinois and Mississippi valleys; the Cottonwood School and Frederick South sections (Leonard and Frye, 1960, p. 27, 28) should be considered supplementary reference sections. The Peoria Loess forms from the merging, beyond the Woodfordian glacial limit, of Morton Loess from below the Shelbyville till with the Richland Loess from the top of the Woodfordian tills.

The fossil molluscan fauna, although sparse in the glacial succession, has been amply described from the contemporary loess

Reference section of Pleistocene deposits at Wedron, including the type section of the Wedron Formation

[Measured in overburden in southwest part of No. 1 Pit of Wedron Silica Co., SE¼ SW¼ sec. 9, T. 34 N., R. 4 E., LaSalle County, Ill., as exposed in 1964]

	Thickness (ft)
Pleistocene Series:	
Wisconsinan Stage:	
Woodfordian Substage:	
Richland Loess:	
15. Loess, leached; largely included in surface soil	3.0
Wedron Formation:	
14. Sand and gravel, poorly sorted, lenticular	3.0
13. Till (Farm Ridge), silty, yellow-gray, calcareous	4.0
12. Sand and gravel, calcareous	2.0
11. Till (Cropsey), silty, bouldery, gray, calcareous	3.0
10. Sand, calcareous, tan	0.5

Reference section of Pleistocene deposits at Wedron, including the type section of the Wedron Formation—Continued

	Thickness (ft)
Pleistocene Series—Continued	
Wisconsinan Stage—Continued	
Woodfordian Substage—Continued	
Wedron Formation—Continued	
9. Till (Cropsey), tan, oxidized, calcareous	5.0
8. Silt and some sand, laminated, gray, calcareous	2.0
7. Till (Normal), silty, gray, calcareous; contains sparse pebbles	3.0
6. Sand and silt, gray, calcareous	1.0
5. Till (Bloomington), pink, bouldery, massive, tough, calcareous; indistinct boulder pavement in middle part	15.0
4. Till (Shelbyville), gray and tan, bouldery, compact, calcareous; sharp contact and indistinct boulder pavement at top	3.0
3. Sand and gravel (pro-Shelbyville outwash), tan, loose, calcareous; locally crossbedded and generally well bedded; irregular erosional contact at base; thickness varies (maximum thickness given here)	20.0
Farmdalian Substage:	
Farmdale Silt:	
2. Silt, clayey, pink to red and red-brown, calcareous; massive to indistinctly bedded, but locally thin bedded and blocky; locally contains small lenses of fine sand; radiocarbon date of 24,000±700 (W-79) determined on wood; conformable on unit below, but upper contact erosional and irregular; thickness varies (maximum thickness given here)	20.0
1. Silt, blue-gray and tan, massive, compact, calcareous; contains some clay and fine sand, and locally sandy streaks near the top; contains molluscan fauna described by Leonard and Frye (1960); radiocarbon date of 26,800±700 (W-871) determined on twigs and wood fragments from upper part; some zones strongly contorted by frost action; basal contact is irregular on eroded surface of St. Peter Sandstone (Ordovician); thickness varies (maximum thickness given here)	25.0
Maximum total thickness of Pleistocene deposits	109.5

sequence. The radiocarbon dates from the underlying Farmdale Silt place a limit on the maximum age of the substage, and those from the overlying Twocreekan deposits, a limit on the minimum age. Dates determined on fossil shells from the Peoria Loess in Illinois have ranged from 20,300±400 (W–870) to 13,700±230 (I–1720). The oldest known radiocarbon date from the Woodfordian in Illinois, 20,700±650 (W–399), was determined on wood

from the upper part of the Morton Loess. The many dates from the Two Creeks deposits of Wisconsin (Broecker and Farrand, 1963) serve to limit the end of the substage and give it an approximate range, in radiocarbon years from 22,000 B.P. to 12,500 B.P.

TWOCREEKAN SUBSTAGE

The Twocreekan was defined as a substage by Frye and Willman (1960), who used Thwaites and Bertrand's (1957) description of the typical Two Creeks deposits of east-central Wisconsin as the type. Thwaites and Bertrand (1957, p. 856) stated that more than 10 feet of lake clay overlies a till and is overlain locally by silt and sand, on which occurs the well-known forest bed. This succession of deposits is the type for the Twocreekan Subtage (Black and others, in Schultz and Smith, 1965a, p. 66–70). More than a dozen radiocarbon dates have been determined for the forest bed by Chicago, Washington, and Lamont laboratories (Broecker and Farrand, 1963). On the basis of the sediments below the dated forest bed and the range in radiocarbon dates obtained, it seems reasonable to consider that the radiocarbon years of the Twocreekan Substage span from about 12,500 B.P. to about 11,000 B.P.

VALDERAN SUBSTAGE

The Valderan Substage was named by Frye and Willman (1960) and was based on the Valders till of eastern Wisconsin as described by Thwaites (1943) and Thwaites and Bertrand (1957). The base of the substage was defined as the contact of Valders till on the Two Creeks deposits in east- central Wisconsin, but the upper limit was defined as an arbitrary radiocarbon age of 5,000 B.P. It was judged that at about that time, the return of sea level approximately to equilibrium near its present position indicated that the continental ice cap had completely dissipated. Because such a definition does not meet the requirements of the Stratigraphic Code (American Commission on Stratigraphic Nomenclature, 1961), we here define the upper limit of the Valderan Substage as the top of the Cochrane till and its contact with overlying thin discontinuous post-Cochrane deposits in the James Bay Lowland of Ontario, Canada (Hughes, 1956, p. 5; 1965).

APPLICATION OF THE STRATIGRAPHIC CODE

Among American students of the Pleistocene, there have been differences in interpretations of the Stratigraphic Code (American Commission on Stratigraphic Nomenclature, 1961) as it is ap-

plied to the glacial succession. These differences, or misunderstandings, may have been prompted by a statement about the misuse of the term "Stage." The statement is as follows (American Commission on Stratigraphic Nomenclature, 1961, p. 659):

> The terms "stage" and "substage" were authorized for climatic subdivisions of the Quaternary Period by the 1933 Code. This usage has led to confusion and is here specifically rejected. "Stage" and "substage" are time-stratigraphic terms and should be used for Quaternary rocks as for other parts of the column.

It has been our intention here to adhere strictly to this admonition.

The Code clearly specifies (American Commission on Stratigraphic Nomenclature, 1961, p. 657, 658) (1) that time-stratigraphic units must be based on actual sections or sequences of rocks, (2) that the upper and lower limits should be defined in the rock succession of the type area and should set the unit apart as representing a significant geologic episode, but that the boundaries of time-stratigraphic units in other than the type area may fall within rock-stratigraphic or biostratigraphic units, (3) that time-stratigraphic units can be extended geographically from their type areas only as criteria of time equivalence are available, and (4) that the radiocarbon dating method is applicable to Quaternary rocks.

It is our judgment that the time-stratigraphic units described herein more fully meet all the requirements of the Stratigraphic Code than do a great many of the generally accepted units in the older part of the rock column. The top surface of a buried soil (top of the A-horizon) defines beyond argument an unconformable contact, and, furthermore, we may be sure that such a surface was exposed to the action of weather, plants, and animals for a sufficient period of time to alter the sediments a significant distance below the surface. The Code does not clearly state whether such a soil profile—properly classed as a soil-stratigraphic unit—may be used as a basis to define a time-stratigraphic unit, but its upper surface clearly is appropriate to define the boundary of a time-stratigraphic unit.

Although the Code states that ideally the boundaries of time-stratigraphic units are isochronous surfaces (and thus independent of lithology, fossils, or other physical criteria), it also states that in actual practice the geographic extension of the unit is generally controlled by stratigraphic features (American Commission on Stratigraphic Nomenclature, 1961, p. 658). The geographic extension of the Wisconsinan Stage by using many radiocarbon dates seemingly permits a closer approach to the

ideal stated in the Code than is true for any other time-stratigraphic unit so far defined.

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