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LATE PLEISTOCENE RADIOCARBON CHRONOLOGY IN IOWA[1]

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ABSTRACT. New radiocarbon dates in Iowa permit a grouping of age values and raise new problems in stratigraphic correlation of late Pleistocene deposits in Iowa and adjacent regions. An older group of ages greater than 29,000 years dates the Iowan substage and pre-Iowan deposits. An old group of ages of 22,900 to 25,100 years dates the Farmdale substage. An intermediate group of ages ranges from 14,000 to 17,000 years. Deposition of Tazewell loess occurred in central Iowa during the period 15,000 to 17,000 years before present. A minimum date of the Tazewell-Cary interstadial is 14,000 years. The Cary maximum in the southern extremity of the Des Moines lobe in Iowa was 14,000 years ago. A young group of ages range from 11,900 to 14,000 years and record Cary glaciation in the southern extremity of the Des Moines lobe. Other parts of the lobe previously classified as Mankato are dated at 11,600 to 11,800 years, and antedate Two Creeks interstadial. A younger group of ages approximating 6,500 to 8,200 years record post-glacial major vegetational and climatic changes in north-central Iowa and subaerial erosion and sedimentation in southwestern Iowa.

INTRODUCTION

A previous article (Ruhe and Scholtes, 1955) described the radiocarbon chronology of the late Pleistocene of Iowa, using the dates from samples determined by W. F. Libby at the University of Chicago radiocarbon laboratory. With the advent of the gas counting method and its associated extended range, additional samples from critical sections in Iowa were selected and submitted to the U. S. Geological Survey Radiocarbon Laboratory. As was anticipated, the discovery of new sections containing suitable dating material, combined with the increased precision of the new C-14 dating method, required that some modification and expansion of the previous chronology be made. It is expected that as more samples are dated from Iowa and from adjacent areas of continental glaciation, the details of the glacial events will become clearer and the problems now presented will be closer to solution. The authors therefore consider this more of a progress report than a final statement.

The chronology is described in terms of the sections from which the dated samples have been taken and have been grouped in sequence from the oldest to the youngest.

OLDER GROUPS

Fayette section.—The Fayette section (fig. 1, J) is a cut along the Chicago, Milwaukee, St. Paul, and Pacific Railroad in the center NE¼ sec. 3, T. 92 N., R. 8 W., Fayette County, Iowa, and is one and a half miles southeast

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of the town of Fayette. The cut occurs on the northern flank of a *paha* that trends NE-SE. The section was reported previously by McGee (1891, p. 488).

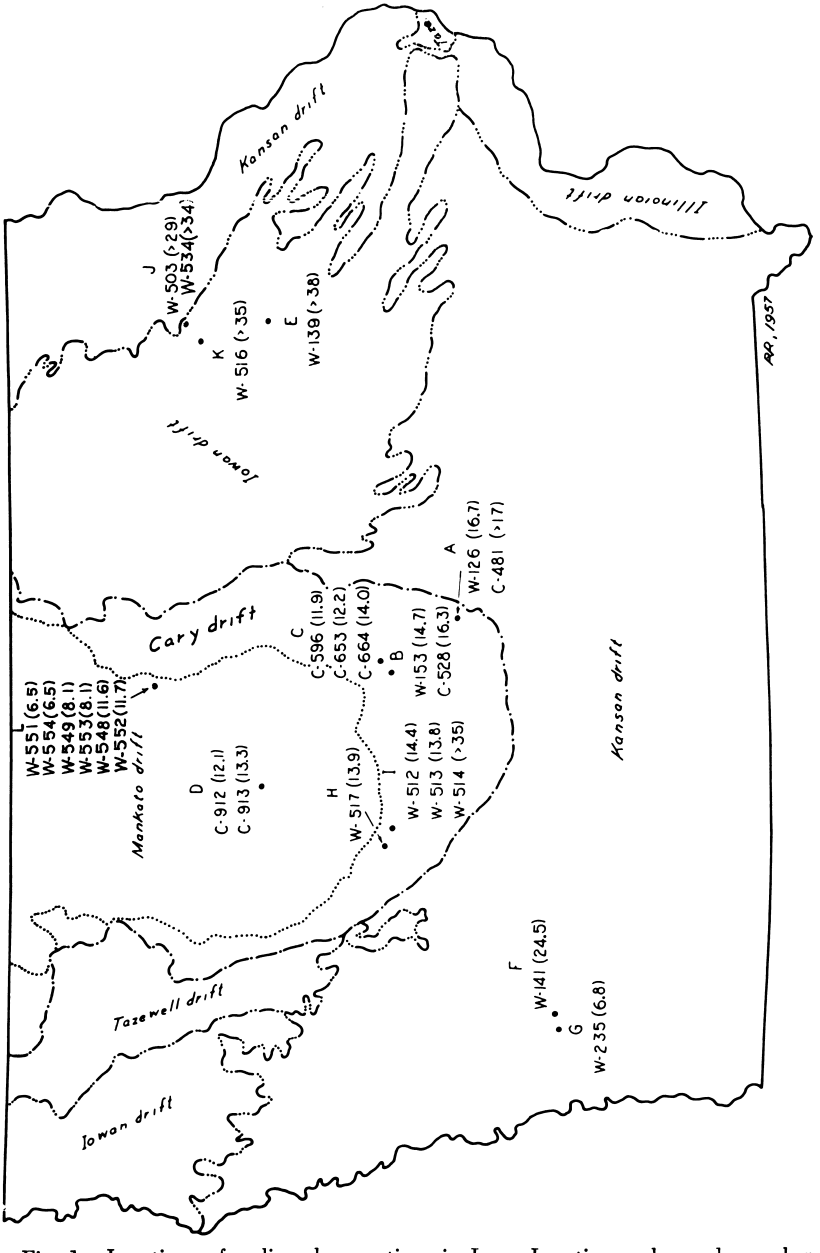


Fig. 1. Locations of radiocarbon sections in Iowa. Location and sample number of radiocarbon section indicated as E W-139 (> 38). Number in parenthesis is age in thousands of years. Glacial-drift borders as shown.

Section description:	Thickness ft.	in.
Iowan till		
4. Yellowish brown (10YR5/4)[3] leached cobbly loam[4] till; mottled with light brownish gray (10YR6/2); friable; subangular blocky; oxidized and leached zone.	9	3
3. Brownish yellow (10YR6/8) to yellowish brown (10YR5/4) calcareous cobbly loam till; firm; coarse angular blocky; oxidized and unleached zone.	5	5
2. Very dark gray (10YR3/1) calcareous cobbly loam till; firm; coarse angular blocky; unoxidized and unleached zone; wood fragments in lower 18 inches with main concentration at contact with underlying zone (radiocarbon sample W-503); zone with wood fragments is McGee's forest bed.	4	10
Pre-Iowan till		
1. Very dark grayish brown (10YR3/2) calcareous clay loam till with dark reddish brown (5YR3/4) iron oxide stain on aggregate faces; firm; medium angular blocky; oxidized and unoxidized and unleached zone transition.	2	7+

A paleosol does not separate stratigraphically the lower till (1) from the basal Iowan till (2). However, the iron oxide stain on the aggregate faces in the lower till (1) suggests that at least an oxidized weathering profile may have been truncated by the overriding Iowan ice.

The Fayette section is located near the margin of the Iowan drift in its type area (fig. 1). Inclusion of abundant wood suggests that Iowan ice encroached on a forested landscape and incorporated fragments of the trees, hemlock[5], in the basal part of the till that subsequently was deposited by Iowan ice. The wood has been dated at $>$ 29,000 years (table 1, W-503), and $>$ 34,000 years in a rerun (W-534).[6]

Maynard section.—The Maynard section (fig. 1, K) is a cut along the Chicago, Rock Island, and Pacific Railroad in the NE¼ sec. 27, T. 92 N., R. 9 W., Fayette County, Iowa, and is a mile south of the town of Maynard. The section was described previously by McGee (1891, p. 489).

Section description	Thickness ft.	in.
Iowan till		
3. Yellowish brown (10YR5/4) leached loam till; friable to firm; angular blocky; oxidized and leached zone.	6	10
2. Brownish yellow (10YR6/8) to yellowish brown (10YR5/4) calcareous loam till; firm; coarse angular blocky; oxidized and unleached zone.	5	0
1. Very dark gray (10YR3/1) calcareous loam till; firm; coarse angular blocky; unoxidized and unleached zone; wood fragments disseminated commonly 30 inches below top of zone and to depth (radiocarbon sample W-516).	5	0+

A lower till, such as in the Fayette section, was not penetrated by shallow borings at the base of the shallow cut.

[3] Munsell soil colors, moist soil.

[4] "Loam" is a texture class which ranges from 7 to 27% clay, 28-50% silt, and $<$ 52% sand.

[5] All woods from Iowa discussed in this paper were identified by Professor D. W. Bensend, Department of Forestry, Iowa State College.

[6] Sample numbers preceded by *W* indicate determination made at the U. S. Geological Survey Laboratory at Washington, D. C. Prefix *C* denotes University of Chicago laboratory determinations.

TABLE 1
Radiocarbon Dates in Iowa

Age group	Substage	Sample	Date	Location	Vegetation
Younger	— epoch	W-551	6,570 ± 200	McCulloch peat bog, Hancock County, Iowa	Grass[1]
		W-554	6,580 ± 200	Middle Silver Creek, Pottawattamie County, Iowa	
		W-235	6,800 ± 300		
		W-549	8,170 ± 200	McCulloch peat bog, Hancock County, Iowa	Oak[1]
		W-553	8,110 ± 200		
Young	Cary substage	W-548	11,660 ± 250	McCulloch peat bog, Hancock County, Iowa	Spruce[1]
		W-552	11,790 ± 250		
		C-596	11,952 ± 500	Cook Quarry, Story County, Iowa	Hemlock
		C-653	12,200 ± 500		
		C-912	12,120 ± 530	Lizard Creek, Webster County, Iowa	Hemlock
		C-913	13,300 ± 900		
Intermediate	Tazewell-Cary interstadial	W-517	13,910 ± 400	Scranton No. 2, Greene County, Iowa	Spruce
		C-664	14,042 ± 1000	Cook Quarry, Story County, Iowa	Hemlock
		W-512	14,470 ± 400	Scranton No. 1, Greene County, Iowa	Fir, hemlock, larch, spruce
		W-513	13,820 ± 400		
	Tazewell substage	W-153	14,700 ± 400	Clear Creek, Story County, Iowa	Hemlock
		C-528	16,367 ± 1000		
		W-126	16,720 ± 500	Mitchellville, Polk County, Iowa	Yew, spruce, hemlock
		C-481	> 17,000		
Old	Farmdale substage	W-141	24,500 ± 800	Hancock, Pottawattamie County, Iowa	Larch
Older	Iowan substage	W-503	> 29,000	Fayette, Fayette County, Iowa	Hemlock
		W-534	> 34,000		
		W-514	> 35,000	Scranton No. 1, Greene County, Iowa	Spruce
		W-516	> 35,000	Maynard, Fayette County, Iowa	Spruce
	Pre-Iowan time	W-139	> 38,000	Independence, Buchanan County, Iowa	Hemlock

[1] Pollen sequence after Lane (1931).

The Maynard section is located in the marginal part of the type Iowan drift, and is approximately six miles southwest of the Fayette cut (fig. 1). At Maynard, as at Fayette, inclusion of wood in the basal part of the Iowan till suggests an overriding of a forested landscape by Iowan ice with resultant incorporation of the wood in the basal part of the Iowan till. The wood has been identified as spruce, and has been dated at > 35,000 (table 1, W-516).

Independence section.—The Independence section (fig. 1, E) is located in a cut along the Illinois Central Railroad in the NW¼ sec. 3, T. 88 N., R. 8 W., Buchanan County, Iowa, approximately 5½ miles east of the town of Independence. The cut is 2½ miles east of Doris station, the type locality for the Iowan drift (Alden and Leighton, 1917, p. 113). The section has been described and discussed previously by Ruhe and Scholtes (1956, p. 264) and by Flint and Rubin (1955, p. 656). However, the section bears more significance than previously accorded now that the Fayette and Maynard sections have been dated.

Section description	Thickness ft.	Thickness in.
Iowan loess		
8. Dark grayish brown (10YR4/2) leached gritty silt; friable; massive; oxidized and leached.	3	2
Iowan till		
7. Pebble band	0	6
6. Yellowish brown (10YR5/8) leached loam till; firm; coarse angular blocky; oxidized and leached zone.	5	8
5. Yellowish brown (10YR5/8) calcareous loam till; firm; coarse angular blocky; oxidized and unleached zone.	2	0
Pro-Iowan (?) or Farmdale (?)		
4. Gray (2.5Y5/0) leached silt; friable; sparse horizontal carbonaceous bands; deoxidized and leached zone.	2	0
Pre-Iowan (?) or pre-Farmdale (?)		
3. Black (2.5Y2/0) leached peat; porous and friable; woody.	1	0
2. Gray (2.5Y5/0) to dark gray (2.5Y4/0) leached silt; friable; massive; deoxidized and leached zone; contains abundant wood fragments; radiocarbon sample (W-139) from this zone, 2 inches below peat.	1	9
1. Gray (10YR5/1) calcareous loam till; firm; coarse angular blocky; unoxidized and unleached zone.	1	6+

In the section (fig. 2) the lower till (1) rises to the surface in the eastern part of the cut where it is truncated by the pebble band. Thus, the continuous pebble band is developed on both the upper till, Iowan (6-5) as well as the lower till, pre-Iowan (1).

The basal, calcareous Iowan till (5) is separated from the buried soil, peat and silt (3-2), by a bed of silt (4) that also is leached of carbonate. The silt (4) grades laterally westward (fig. 2) to oxidized and leached sand, and represents either a pre- or pro-Iowan water-laid sediment. The radiocarbon sample (W-139), dated at > 38,000 years, was contained in the lowermost silt beneath the peat. Wood from the section was identified as hemlock. There is not a well-developed buried soil in the sequence.

The Independence section differs from the Fayette and Maynard sections in that wood of great age is not incorporated in the basal part of the Iowan

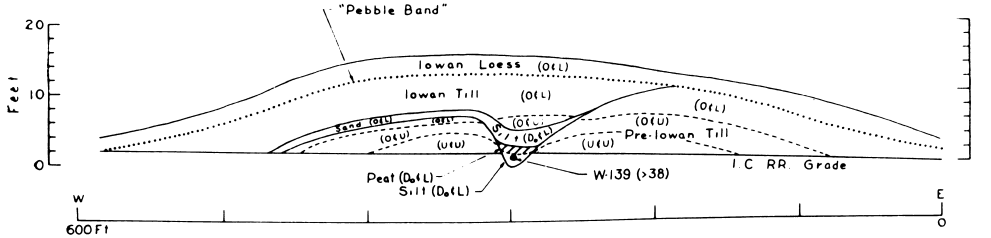


Fig. 2. Scale drawing of Illinois Central Railroad cut, Independence section, Iowa. Symbols: O & L, oxidized and leached; O & U, oxidized and unleached; U & U, unoxidized and unleached; Do & L, deoxidized and leached.

till. but that the wood is separated stratigraphically from the basal Iowan by a buried peat soil and a superposed leached silt and sand bed. The interbedded leached silt and sand does not permit a conclusion that the Iowan ice did or did not advance into the area soon after the peat formed.

Alden and Leighton (1917, p. 95, 99, 100, 111, 202) have described sections in the Iowan drift region in northeastern Iowa where basal Iowan till is underlain by a silt which, in turn, mantles older Pleistocene deposits.

Scranton No. 1 section.—(See Intermediate Group.) In this section (fig. 1, I) an unoxidized and unleached till occurs in the base of the section, and is overlain by an unoxidized and unleached silt that contains a spectacular buried forest in the uppermost part. A paleosol or weathering zone does not separate the lower till from the overlying silt. The silt, in turn, is mantled by unoxidized and unleached Cary till.

The lower part (fig. 4, barren zone) of the buried silt in the section is correlative stratigraphically with the post-Farmdale loess where that loess is the surficial deposit beyond the limits of the Cary drift (figs. 1; 3, F, H, I), and thus may be considered early Wisconsin in age. Because the buried silt in the Scranton section is not separated from the underlying till by a paleosol or weathering zone, the lowermost till also is considered early Wisconsin in age. A wood sample (W-514) was extracted 13½ feet below the top of the lowermost till, and is dated at greater than 35,000 years.

Thus, this section represents the third location (Fayette, Maynard, Scranton No. 1) where wood beyond the present range of radiocarbon dating methods was collected from Iowan or early Wisconsin till. At the fourth location (Independence), an interbedded leached silt and sand separates the Iowan from the horizon of "old" wood.

Hancock section.—The Hancock section (fig. 1, F) is a cut on the Chicago, Rock Island, and Pacific Railroad in Pottawattamie County, Iowa, approximately 2½ miles southwest of the town of Hancock. The section was described in detail by Ruhe and Scholtes (1956, p. 264-265). A wood sample (W-141) was extracted from the A horizon of a buried soil in a loess sheet 3 to 4 feet thick that overlies Loveland loess. Above the sample horizon there is a third loess sheet approximately 30 feet thick. The uppermost loess contains two faunal zones. Based upon Leonard's (1952, p. 11-14) faunal zonations, the uppermost zone is indicative of the Tazewell and the lowermost zone

of the Iowan. On the basis of the stratigraphic position of the radiocarbon horizon beneath an Iowan faunal zone and above the Sangamon paleosol in Loveland loess, the sample horizon was classified by Ruhe (1954, p. 640) as Farmdale. The age of the sample, 24,500 ± 800 years, is in excellent agreement with radiocarbon values (Suess, 1954, p. 470) for the type Farmdale in Illinois at 22,900 ± 900 and 25,100 ± 800 years. Wood from the Hancock section was identified as larch.

Correlation of deposits of Farmdale and Iowan substages.—It is generally recognized that the Farmdale is the earliest substage of the Wisconsin glacial stage and that the Iowan substage was subsequent to the Farmdale (Leighton and Willman, 1950, p. 602; Horberg, 1953, p. 12; Shaffer, 1956, p. 10). Leighton and William defined the Farmdale substage in Illinois as pro-Wisconsin deposits between the Sangamon weathered zone and Iowan loess, and they defined the Iowan substage in Illinois as the loess between the Farmdale and Shelbyville [Tazewell] deposits. Shaffer (1954, p. 455), with qualifications, reconfirmed the younger age of Iowan in eastern Iowa by stating: "If the high terrace of Lake Calvin proves to be equivalent to the Tazewell (Shelbyville) then the Shelbyville portion of the Tazewell and the Iowan would be contemporaneous, and on the basis of priority Shelbyville would be redefined as Iowan. These matters merit further field investigation."

The stratigraphic relationships of Farmdale, Iowan, and Tazewell deposits were determined originally by tracing the loess that occurs on the Iowan drift in eastern Iowa eastward to the margin of the Shelbyville drift in western Illinois (Leighton, 1931, p. 46-51). At the margin of the Shelbyville drift, part of the loess passes under and part over the drift. Paleosols do not separate the lower loess from the interbedded till, or the till from its overlying loess. The lower loess is of Iowan age, and the interbedded till and the upper loess are of Tazewell age (Kay and Leighton, 1933, p. 673). The lower loess (Iowan) overlies a loess that contains a paleosol and youthful profile of weathering in its uppermost part. This basal loess is the "late Sangamon loess" of earlier classification (Leighton, 1931, p. 48), but now the Farmdale loess of current classification (Leighton and Willman, 1950, p. 602-603).

Thus, the classification and correlation of the sequence Farmdale, Iowan, and Tazewell fundamentally is based upon the tracing of the Peorian loess, or more specifically the Iowan increment of the loess, and determining the relationships of the increment to overlying and underlying deposits. Because the increment is not separated from the rest of the Peorian loess by a paleosol, identification and classification of the increment may be somewhat tenuous. For example, in Shaffer's (1956, p. 16-17) recent delineation of Farmdale drift in northwestern Illinois, a loess between the Farmdale and tills of the Shelbyville sub-lobe is classified in all described sections as *Iowan or pro-Shelbyville [pro-Tazewell] loess.*

Radiocarbon dates from the type Iowan drift in Iowa and Farmdale loess in Iowa and the type Farmdale in Illinois suggest that the Iowan may be older than the Farmdale. The ages of wood in unoxidized and unleached Iowan till range from more than 29,000 years to more than 35,000 years (Fayette, W-503, > 29,000 years, W-534, > 34,000 years; Maynard, W-516, >

35,000 years; Scranton No. 1, W-514, > 35,000 years). The ages of wood from the Farmdale range from 22,900 years to 25,100 years (Hancock, Iowa, W-141, 24,500 ± 800 years; Farm Creek, Illinois, W-68, 22,900 ± 900 years and W-69, 25,000 ± 800 years).

In contrast to the "greater than" dates derived from wood in the Iowan till of Iowa, determinations made on wood found between Farmdale loess and overlying Tazewell till in the supposed loess correlative in Illinois, have yielded dates of from 20,340 to 22,450 years. This loess has been dated by three samples (Farm Creek, Illinois, W-349, 20,340 ± 750; Rock Creek, Illinois, W-483, 20,500 ± 600; East Bureau Creek, Illinois, W-334, 22,450 ± 1,000) and the dates obtained are in complete accord with the dates from wood in the overlying and underlying deposits. The fact that these dates are what one might expect for a loess between Farmdale and Tazewell deposits does not verify the correlation of the loess as Iowan. Rather, the opposing dates of the Iowan till of Iowa, and the Iowan loess of Illinois present an unresolved problem of field correlation.

Identification of an Iowan faunal zone above the Farmdale at Hancock by Ruhe (Rubin and Suess, 1955, p. 484) was based upon the faunal zonations of Leonard (1952, p. 11-14). Leonard's faunal zonations, in turn, are based upon the somewhat tenuous physical stratigraphic correlations of Farmdale, Iowan, and Tazewell in eastern Iowa and western Illinois (Leonard, 1952, p. 15; Frye and Leonard, 1952, p. 128).

Mitigative evidence in the lack of agreement between radiocarbon ages and accepted stratigraphy of Farmdale and Iowan may occur in the Independence section in Iowa (fig. 2). There the basal calcareous Iowan till is separated from the buried peat (<38,000 years) by an interbedded, leached silt and sand. Is this leached zone correlative of Farmdale or of the pro- or earliest Iowan basal, leached loess (fig. 3, E-F)? The problem warrants further investigation.

However, it should be noted that three sections of Iowan age in Iowa contain wood of radiocarbon age similar to the old till in Ohio, typified by the Sidney section (Flint and Rubin, 1955, p. 651; Forsyth and La Rocque, 1956; Rubin, 1956; Goldthwait, in press), that may indicate a pre-Farmdale Wisconsin glaciation. If this be substantiated, then the name Iowan would have priority for this earliest of post-Illinoian glaciations.

INTERMEDIATE GROUP

In Iowa a considerable number of radiocarbon dates are included in an intermediate group that is divisible into two age ranges, one of 15,000 to 17,000 years, and a second at 14,000 years. Sections of the older category have been described previously: Mitchellville section (fig. 1, A; Ruhe and Scholtes, 1955, p. 83-84) and Clear Creek section (fig. 1, B; Ruhe and Scholtes, 1955, p. 84-88). These two sections are very similar stratigraphically. A thin Cary till caps a buried loess within which, and at a considerable number of feet below the till, forests beds occur. The Mitchellville forest bed has been twice dated (table 1: C-481, >17,000 years; W-126, 16,720 ± 500 years)

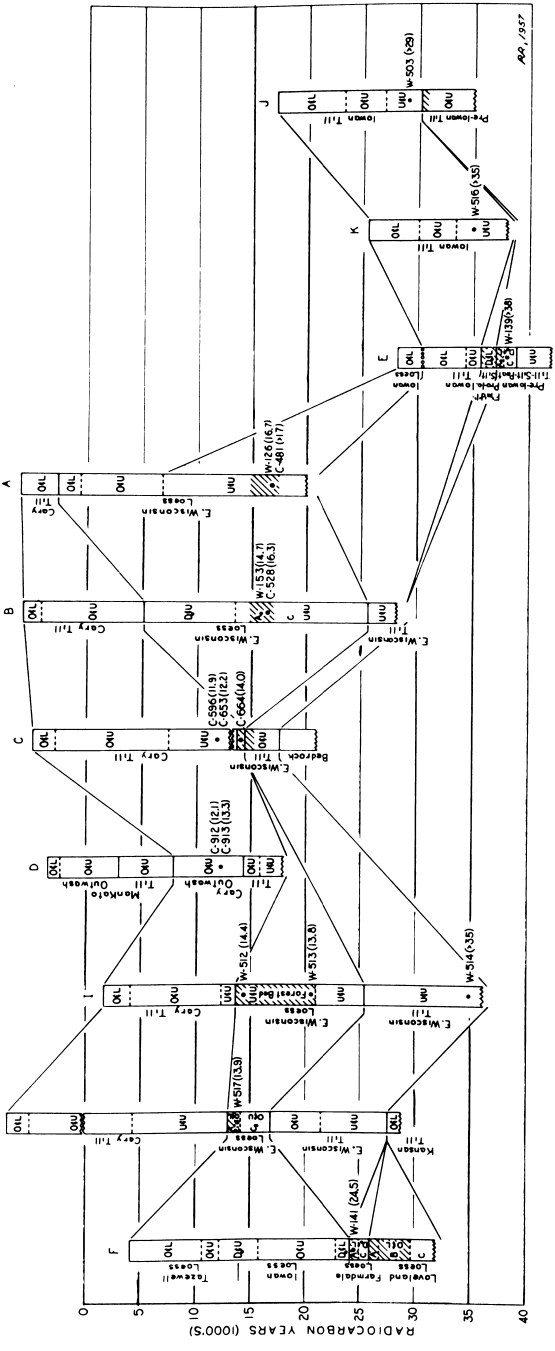


Fig. 3. Correlation of radiocarbon sections in Iowa. Symbols: See fig. 2. A, B, C are horizons of buried soils. W-139 (> 38) is sample location and number. Number in parenthesis is age in thousands of years.

as has the Clear Creek forest bed (C-528, 16,367 ± 1,000 years; W-153, 14,700 ± 400 years).

Considerable argument has developed concerning the correlation and significance of these sections (Horberg, 1955, p. 280-281; Ruhe, 1956; Leighton, 1956). The present writers reconfirm classification of the buried loess as Tazewell rather than pro-Cary and that the dates from 15,000 to at least 17,000 years conform to the period of Tazewell loess deposition. Further evidence to support this conclusion is found in two new sections (Scranton No. 1 and No. 2) recently exposed within the Cary drift in central Iowa.

Scranton No. 1 section.—This section is a road cut (figs. 1, I; 4) along the recently relocated U. S. Highway 30 in the SW¼ sec. 33, T. 84 N., R. 31 W., Greene County, Iowa, approximately 4 miles east of the town of Scranton, Iowa. The road cut is on the east valley slope of Raccoon River.

Section description	Thickness ft.	Thickness in.
Cary till		
6. Brown to dark brown (10YR4/3) leached cobbly loam till; friable; subangular blocky; oxidized and leached zone.	3	6
5. Yellowish brown (10YR5/6) calcareous cobbly loam till; firm; coarse angular blocky; oxidized and unleached zone.	12	4
4. Very dark gray (2.5YR3/0) calcareous cobbly loam till; firm; coarse angular blocky; unoxidized and unleached zone.	2	0
Early Wisconsin silt		
3. Very dark gray (2.5YR3/0) calcareous silt loam; friable; massive; fossiliferous; forest bed—tree stumps with root systems in place at many levels within zone; radiocarbon sample W-512 from root system of tree in place in upper foot of zone; sample W-513 from root system of tree in place in lower foot of zone.	11	0
2. Dark gray (2.5YR4/0) calcareous silt loam; friable; massive; fossiliferous; "barren zone" disseminated fragments of wood, but no tree stumps with root systems in place.	6	8
Early Wisconsin till		
1. Greenish yellow (5GY5/1-6/1) calcareous cobbly loam till; firm; coarse angular blocky; unoxidized and unleached zone; polished and varnished pebbles at top of till, "pebble band"; radiocarbon sample W-514 in basal foot of this zone.	13	6+

A paleosol or weathering zone does not separate the lower till from the overlying silt. Calcareous silt is in contact with calcareous till, although interrupted by an intercalated pebble band. This is the normal relationship of thick loess on Iowan till or thick loess on Tazewell till in northwestern Iowa. The radiocarbon sample W-514 from the lower till is dated at greater than 35,000 years and conforms to the age range of the Fayette (W-503, W-534) and Maynard (W-516) samples from the type Iowan of northeastern Iowa.

The lower part of the silt (barren zone) is massive and contains a gastropod fauna that is disseminated throughout the zone. Physical characteristics of the silt are such that it would be difficult to distinguish the silt from recognized loess where the latter occurs as the surficial deposit beyond the limits of the Des Moines lobe. Thus, the lower part (barren zone) of the silt is considered to be loess. Its faunal assemblage (table 2) is nearly identical to the uppermost faunal zone of loess of the Hancock section (fig. 1, F),

TABLE 2
Faunas of Radiocarbon Sections

Species	Hancock						Scranton No. 2			Scranton No. 1			Clear Creek					
	Lower zone			Upper zone									Below Forest Bed			Above Forest Bed		
	I	Tr	T	I	Tr	T	I	Tr	T	I	Tr	T	I	Tr	T	I	Tr	T
Columella alticola						*			*			*						*
Euconulus fulvus									*			*						*
Hendersonia occulta						*			*									*
Succinea ovalis						*			*			*						*
Discus cronkhitei		*	*					*	*		*	*		*	*		*	*
Discus shimeki		*	*		*	*					*	*						
Succinea grosvenori		*	*		*	*		*	*		*	*		*	*		*	*
Vertigo modesta		*	*					*	*		*	*					*	*
Hawaii minuscula	*	*	*				*	*	*				*	*	*			
Pupilla blandi							*	*	*	*	*	*	*	*	*	*	*	*
Pupilla muscorum							*	*	*				*	*	*			
Vallonia gracilicosta	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Succinea avara							*	*		*	*		*	*		*	*	
Lymnaea parva										*			*					

I—Iowan, Tr—transition, T—Tazewell (Faunal zonation after Leonard, 1952).

Scranton No. 1 section (H), and the uppermost faunal zone of the Clear Creek section (B). It appears certain that the buried loess of the Scranton No. 1 section and those of Scranton No. 2 and Clear Creek are the same stratigraphic horizon as the loess of the Hancock section (fig. 3, F-H-I-B).

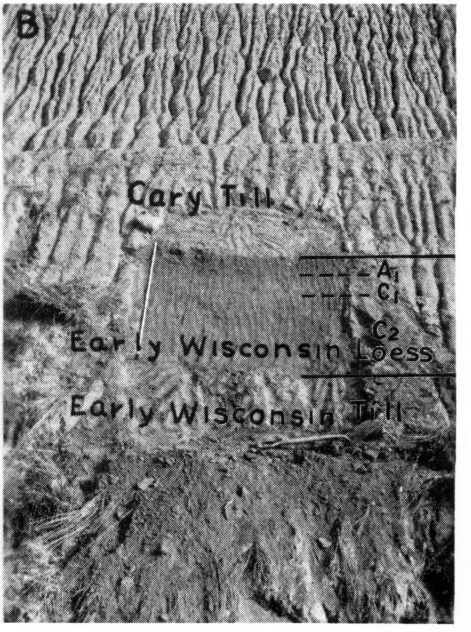
The forest bed in the upper 11 feet of the buried silt is an outstanding feature. Tree stumps with root systems in place occur at many levels throughout the zone (pl. 1, A). A horizontal bench in the forest bed cut during construction showed as many as 15 to 20 trees per 50 square feet of area. Wood from the section has been identified as hemlock, larch, fir, and spruce.

However, the silt containing the forest bed is separated from the underlying "barren zone" by an erosion surface. Fragments of wood and gastropod shells are concentrated along a bedding plane, almost continuous throughout the section, at the base of the forest bed. Other bedding planes with concentrations of wood fragments and gastropod shells occur within the forest bed. These evidences suggest that the silt which contains the forest bed is a waterlaid sediment that was derived from a source of early Wisconsin loess.

Wood in the forest bed just below the contact of the Cary till is dated at 14,470 ± 400 years (table 1, W-512). Trunks of trees rooted in this zone were bent over toward the south. The date of 14,470 ± 400 years is in excellent agreement with a date (table 1: C-664, 14,042 ± 1,000 years) from the Cook Quarry section (Ruhe and Scholtes, 1955, p. 88-90) where wood was collected just below the base of the Cary till. These radiocarbon values

PLATE 1

Spruce tree rooted in place in forest bed of Scranton No. 1 section, Iowa. Trunk of a second tree is in right background.



Buried soil in early Wisconsin loess between overlying Cary till and underlying early Wisconsin till in Scranton No. 2 section, Iowa. A_1, C_1, C_2 are horizons of buried soil.

date the earliest advance of Des Moines lobe Cary ice in the latitude of the sections (fig. 1).

Wood collected 10 feet below sample W-512 but just above the basal bedding plane of the forest bed silt is dated at 13,820 ± 400 years (table 1, W-513).

In the Scranton No. 1 section the buried forest is a gigantic Regosolic paleosol[7] that stratigraphically separates the loess (barren zone) from the overlying Cary till. The loess is most logically Tazewell in age and not pro-Cary as Horberg (1955, p. 281) has suggested for the similar stratigraphic sections at Clear Creek and Mitchellville (fig. 1, B and A).

Scranton No. 2 section.—This section (figs. 1, H; 4) is a cut on country road M on the south valley slope of Raccoon River in the NE¼ sec. 26, T. 84 N., R. 32 W., Greene County, Iowa, approximately 2½ miles north of the town of Scranton, Iowa.

[7] A *Regosol* is a soil developed in unconsolidated material, and which has few or no clearly expressed soil characteristics. A Regosol generally has an A-C profile. A *paleosol* is a "fossil" soil that was formed on a landscape during the geologic past. Sedimentation subsequent to pedogenesis buried and preserved the soil profile. This kind of paleosol is a buried soil.

Section description	Thickness ft.	Thickness in.
Cary till		
14. Dark brown (10YR3/3) leached cobbly loam till; firm; coarse angular blocky; unoxidized and leached zone.	3	0
13. Yellowish brown (10YR5/4) and dark yellowish brown (10YR4/4) mottled with gray (10YR5/1) calcareous cobbly loam till; firm; coarse angular blocky; oxidized and unleached zone.	28	0
12. Very dark gray (10YR3/1) calcareous cobbly loam till; firm; coarse angular blocky; unoxidized and unleached zone.	12	10
Early Wisconsin loess		
11. Very dark gray (10YR3/1) to very dark grayish brown (10YR3/2) weakly calcareous silt loam; friable; weak fine granular; A_{11b}[8] horizon of Tazewell-Cary interstadial soil.	0	6
10. Very dark grayish brown (10YR3/2) to dark brown (10YR3/3) very weakly calcareous silt loam; friable; weak fine granular; A_{12b} horizon of Tazewell-Cary interstadial soil.	0	6
9. Dark grayish brown (2.5YR4/2) to very dark grayish brown (2.5YR3/2) leached silt loam; friable; massive; C_{1b} horizon of Tazewell-Cary interstadial soil; tree stumps with root systems in place in A_1-C_1 horizons of buried soil (radiocarbon sample W-517).	0	7
8. Dark grayish brown (2.5YR4/2) weakly calcareous silt loam; friable; massive; fossiliferous; C_{2b} horizon of Tazewell-Cary interstadial soil.	1	8
7. Olive brown (2.5YR4/4) calcareous silt loam; friable; massive; fossiliferous, oxidized and unleached loess.	0	9
Early Wisconsin till		
6. Dark yellowish brown (10YR4/4) calcareous cobbly loam till with reddish brown (2.5YR4/4) iron oxide stain on aggregate faces in upper foot of zone; firm; coarse angular blocky; oxidized and unleached zone.	6	11
5. Gray (10YR5/1) to grayish brown (10YR5/2) calcareous cobbly loam till; firm; coarse angular blocky; unoxidized and unleached zone.	9	2
Kansan till		
4. Yellowish brown (10YR5/4) leached cobbly clay loam[9] till; firm; plastic; coarse angular blocky; oxidized and leached zone.	1	10
Pro-Kansan sand and gravel		
3. Strong brown (7.5YR5/6) leached gravelly sand; bedded.	2	6
2. Yellowish brown (10YR5/8) leached sand.	1	6
1. Strong brown (7.5YR5/6) leached sand; iron-oxide cemented, indurated pan (must be broken with hammer); underlain by yellowish brown, leached, friable, bedded sands and gravels.	1	0

The lower till and underlying sands and gravels (fig. 4) are probably pre-Wisconsin (Kansan) in age. The horizons are leached to a combined depth of more than 10 feet. The till above the Kansan is considered early Wisconsin in age because of its relationship to the overlying buried loess. Oxidized and unleached till is in contact with oxidized and unleached loess. A paleosol or weathering zone does not separate the two. This conformable relationship is characteristic where thick loess overlies Iowan and Tazewell tills in northwestern Iowa.

[8] Soil horizon nomenclature follows Soil Survey Manual (1951, p. 173-188).

[9] "Clay loam" is a texture class which ranges from 27 to 40% clay, 20 to 45% sand, and the remainder of silt.

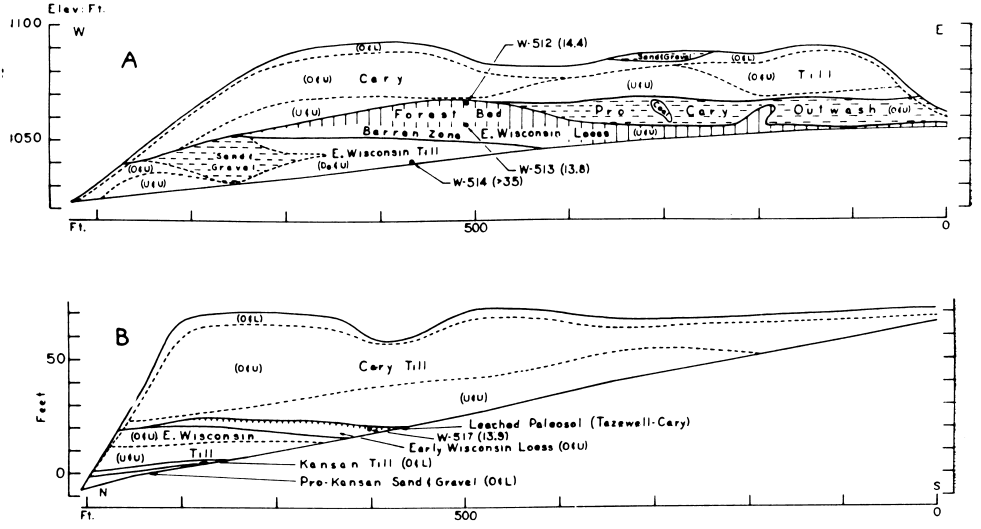


Fig. 4. Scale drawings of Scranton No. 1 section, Iowa (A) and Scranton No. 2 section, Iowa (B). Symbols: see fig. 2.

The buried loess in the section contains a fauna that is almost identical to the faunas of the surficial Tazewell loess in the Hancock section, the buried loess in the Scranton No. 1 section, and the upper zone of the buried loess in the Clear Creek section (table 2). This is one of the bases on which the buried loess of the Scranton No. 2 section is classified as early Wisconsin. The loesses, surficial and buried, of the four sections undoubtedly are correlative (fig. 3, F-H-I-B).

A Regosolic paleosol (pl. 1, B) occurs in the uppermost part of the buried loess which is overlain by Cary till. The paleosol is weakly developed. There is no clay accumulation in the profile (fig. 5). Organic matter has accumulated in greatest quantity in the upper 12 inches of the paleosol. Distribution of organic matter with depth in the profile is comparable to modern Regosols (fig. 5). The paleosol was partially leached of carbonates[10] to a depth of 19 inches (fig. 5), although resaturation by carbonates from the overlying calcareous Cary till increases progressively upward toward the uppermost horizon of the buried loessial soil. The interbedded loess is differentiated distinctly from the overlying and underlying tills on the basis of sand content (fig. 5). Similarly, organic matter and carbonate contents differentiate the loess from the tills (fig. 5), and emphasize the paleosol development.

Wood from a tree stump rooted in place in the A_1-C_1 horizons of the buried soil has been dated at 13,910 ± 400 years (table 1, W-517). The wood was identified as spruce. The date is in excellent agreement with dates from Scranton No. 1 section at 14,470 ± 400 years and Cook Quarry section at 14,042 ± 1,000 years for comparable stratigraphic horizons. These dates

[10] In the field the horizon of the paleosol from 12 to 19 inches did not effervesce in strong concentrations of acid. The horizon was recorded as leached.

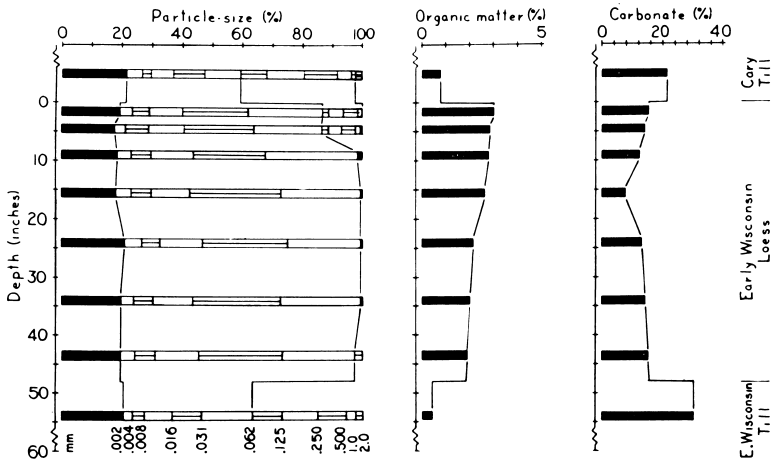


Fig. 5. Characteristics of paleosol in Early Wisconsin loess in Scranton No. 2 section, Iowa.

place the maximum of Cary ice advance of the Des Moines lobe at this latitude (fig. 1, H. I. C) as approximately 14,000 years before present. The maximum limit of Cary ice advance, to the city of Des Moines, is only 30 miles south of the latitude of the three sections, so the Cary maximum in Iowa can be dated at approximately 14,000 years ago.

The occurence and dating of the tree in a paleosol beneath Cary till provides a minimum date of 14,000 years for the Tazewell-Cary interstadial in Iowa. The occurrence of the paleosol in the uppermost part of the loess also lends support to the conclusion that the loess buried beneath Cary drift in the Des Moines lobe area is Tazewell in age.

It is shown therefore that deposition of Tazewell loess was occurring in central Iowa during the period from 15,000 to at least 17,000 years ago (table 1: Clear Creek at 14,700 $\pm$ 480, 16,367 $\pm$ 1,000; Mitchellville at 16,720 $\pm$ 500, $>$ 17,000), but that the deposition terminated prior to 14,000 years ago.

YOUNG GROUP

Two sections in central Iowa have radiocarbon dates that range from 11,900 to 13,300 years. These dates apply to the drifts of the Des Moines lobe.

Cook Quarry section.—This section has been described previously (fig. 1, C; Ruhe and Scholtes, 1955, p. 88-90). Wood extracted from the unoxidized and unleached Cary till has been dated at 11,952 $\pm$ 500 years (table 1, C-596) and 12,200 $\pm$ 500 years (C-653). The section occurs in the marginal part of the Des Moines lobe that was reclassified as Cary in age (Ruhe, 1952, p. 47-49).

A comparison of these dates with the radiocarbon date from an horizon just below the base of the Cary till in the same section (table 1, C-664) and with the dates of the sections Scranton No. 1 and No. 2 (table 1, W-512,

W-517) shows that Cary glaciation was active in the latitude of these sections from 11,900 to 14,000 years ago.

Lizard Creek section.—The section has been described previously (fig. 1, D; Ruhe and Scholtes, 1955, p. 90-91). The section occurs in the inner part of the Des Moines lobe that was considered Mankato in age (Ruhe, 1952, p. 52-54). Wood that was contained in an outwash gravel between a lower and an upper till, was dated at 12,120 ± 530 years (table 1, C-912) and 13,300 ± 900 years (C-913). These dates are in good agreement with the young dates from the Cook Quarry section (C-596, C-653). But in the Lizard Creek section an upper till overlies the outwash that contains the radiocarbon horizon. The upper till must be younger than the till of Cook Quarry (fig. 3, B) and the outwash of Lizard Creek (fig. 3, C). The upper till in Lizard Creek was considered Mankato in age.

Classification of drifts of the Des Moines lobe.—Recently Wright and Rubin (1956, p. 625), on the basis of certain difficulties in delineating Cary and Mankato deposits in the Des Moines lobe and with reference to radiocarbon ages that antedate the Two Creeks interstadial, suggested that the whole of the Des Moines lobe should be placed in the Cary. Zumberge and Wright (1956, p. 65-81) have reaffirmed in greater detail this classification. The arguments of reassigning the whole of the Des Moines lobe to Cary are based primarily on the evidence that most of the radiocarbon dates of the Des Moines lobe are older than Two Creeks (11,400 years).

It should be noted, however, in the extreme southern portion of the Des Moines lobe that Cary events are recorded by radiocarbon dates that range from a maximum of 14,000 years to a minimum of 11,900 years. The latter age is approaching Two Creeks time. All of these events are recorded in front of the Altamont moraine, which was recognized by Ruhe (1952, p. 52-54) as the margin of the Mankato of the Des Moines lobe.

Further evidence, that portions other than the outermost margin of the Des Moines lobe in Iowa may antedate Two Creeks, is found in the McCulloch peat bog which is located in the center S½ sec. 32, T. 94 N., R. 24 W., Hancock County, Iowa (fig. 1, L). In the bog 3½ feet of black (10YR5/1) to very dark brown (10YR2/2) fibrous, woody peat overlies a gray (10YR5/1), calcareous, fossiliferous, organic muck, Six inches of gray sand and gravel occur at the base of the bog sediments that overlie gray, calcareous till. The top of the till is 14 to 15 feet below the surface of the bog. The bog occurs at the inner margin of the Altamont moraine, and occurs also 16½ miles southeast of the outer margin of the massive Algona moraine.

Lane (1931) has described in detail the pollen sequence of the McCulloch peat bog.

Two radiocarbon dates have been determined from the basal 12 inches of organic muck of the bog sediment. An age of 11,660 ± 250 years (table 1, W-548) was determined from the fraction of the muck insoluble in hot NaOH, and a date of 11,790 ± 250 years (W-552) from the fraction of the sample from the same horizon that was soluble in hot NaOH. These separations of the lignin from the cellulose were made in the laboratory to eliminate the possibility of contamination by younger organic matter from above, the lignin

being the most mobile. Both of these values, which are a minimum for the underlying till, predate Two Creeks (11,400 years). Thus, it appears that a portion of the Des Moines lobe associated with the Altamont moraine also is older than Two Creeks.

But if the whole of the Des Moines lobe is to be considered Cary (i.e., pre-Two Creeks), many more events must be crowded in the period 11,700-11,600 to 11,400 years. Construction of the massive Algona moraine in Iowa is required. Then too, the many morainal systems of the lobe in Minnesota must be considered. Before the whole of the Des Moines lobe can be classified as Cary, more evidence must be available than is presently at hand.

Leighton's (1957, p. 109) suggestion may be pertinent, that the Valders be added to the substages of the Wisconsin, succeeding the Mankato. Thus, the Mankato would be maintained as a separate substage but of pre-Two Creeks age rather than post-Two Creeks as presumed previously.

YOUNGER GROUP

Middle Silver Creek section.—This section (fig. 1, G) is a gully fill exposed in a cut along the relocated Chicago, Rock Island, and Pacific Railroad, along the south line sec. 13, T. 76 N., R. 41 W., Pottawattamie County, Iowa. The gully fill truncates progressively downward a late Wisconsin gleyed zone in the upper part of post-Farmdale loess (Ruhe and Scholtes, 1956, p. 271-272), post-Farmdale loess, Farmdale loess, and Sangamon soil in Loveland loess. Thus, the gully fill must post-date late Wisconsin. Carbon extracted by combustion from the basal foot of the fill of 17 feet is dated at 6,800 ± 300 years (Rubin and Suess, 1956, p. 446, W-235).

The gully fill of Middle Silver Creek section is part of a cut and fill surface that occurs in regional distribution throughout southwestern Iowa, and records post-glacial or Recent subaerial erosional modification of the landscape.

McCulloch peat bog section.—Lane (1931, p. 167) on the basis of pollen analyses showed a sequence of changes in the peat bed from the base upward which are: (1) spruce forest, (2) mixed fir, birch, and spruce, (3) birch with fir and oak, (4) oak with birch and grasses, and (5) grassland vegetation with two intercalated strong semi-arid elements indicated by major proportions of amaranths.

Radiocarbon samples were collected from Lane's spruce zone, coniferous-deciduous forest transition zone, and the zone indicating the beginning of grass dominance. The basal spruce zone is dated at 11,660 ± 250 years (fig. 1L; table 1, W-548) and 11,790 ± 250 years (W-552). The coniferous-deciduous forest transition is dated at 8,170 ± 200 years (W-549) and 8,110 ± 200 years (W-553). The beginning of the dominance of grass is dated at 6,570 ± 200 years (W-551) and 6,580 ± 200 years (W-554).[11]

Lane (1931, p. 169) inferred from the pollen sequence a climatic change from cool, moist of the coniferous period to a warming trend which accompanied the change from coniferous to deciduous forms (now dated at

[11] The first of each pair of values was determined from the fraction insoluble in hot NaOH, and the second of each pair from the fraction soluble in hot NaOH.

11,600 to 8.100 years), and a gradual dessication of the climate culminating just prior to grass dominance (now dated at 8.100 to 6.500 years). The warm, dry grassland climate has been continuous from 6.500 years to the present, with the exception of a stronger semi-arid element during that time.

Lane's "culmination of climatic dessication just prior to grass dominance" encompasses the age of the basal gully fill in loess in southwestern Iowa, which is dated at 6.800 ± 300 years (table 1, W-235). Such climatic dessication may have prepared the loessial landscape for severe gullying.

SUMMARY

The following tentative conclusions seem valid from the evidence at hand. It is recognized that further field and laboratory studies are necessary to test their validity.

1. A possible interpretation of radiocarbon dates from Iowa places the Iowan substage in an older position than the Farmdale, rather than younger, as hitherto believed. Farmdale is dated in Iowa at 24.500 years B.P. (before present): Iowan till yields wood with dates beyond the present range of radiocarbon dating.

2. Tazewell loess was being deposited in Iowa from sometime prior to 17,000 to approximately 15.000 years ago.

3. The Cary advance of the Des Moines lobe reached its maximum southern extent approximately 14.000 years ago. Cary glacial activity in the southern extremity of the lobe is recorded during the period of 11.900 to 14.000 years B.P.

4. A part of the Des Moines lobe associated with the Altamont moraine in Iowa dated at 11.600 to 11,800 years B.P. antedates Two Creeks dated at 11.400 years B.P.

5. Post-glacial major vegetational and climatic changes in Iowa are recorded at 8.200 to 8.100 and 6.600 to 6,500 years ago. A gully cycle may be related to the latter major climatic change.

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