IOWA GEOLOGICAL SURVEY
IOWA CITY, IOWA
H. GARLAND HERSHEY, Director and State Geologist

REPORT OF INVESTIGATIONS 7

IOWAN DRIFT PROBLEM, NORTHEASTERN IOWA

by

R. V. RUHE, W. P. DIETZ, T. E. FENTON, and G. F. HALL

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In Cooperation with
Soil Conservation Service, U. S. Department of Agriculture,
Iowa Agriculture Experiment Station, Ames

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Background

The Iowan drift has long been a center of controversy. In the earlier days, arguments involved the questions: (1) Is there an Iowan drift? (2) If it did exist, was it of pre-Wisconsin age, or was it a separate stage or a part of the Wisconsin? A related argument concerned the relation of loess and pebble band (stone line) to the drift. The questions involved: (1) Were the loess and stone line closely related in time to the drift, or (2) did the stone line between the loess and the till represent a hiatus of considerable time? McGee (1891), Calvin (1899), Alden and Leighton (1917), and Kay and Apfel (1929) developed the ideas through the years that the Iowan did exist and was a separate stage between the Illinoian and Wisconsin. Later, however, the Iowan was assigned to the earliest substage of the Wisconsin (Leighton, 1931, 1933; Kay and Graham, 1943). Accordingly, the stone line and loess were recognized as being closely related in time to the drift. On the other hand, Leverett (1909, 1926, 1939) contended: (1) that the Iowan was a late phase of Illinoian glaciation; (2) that the stone line had been formed by running water and much time was involved in its formation, and (3) that the loess was much younger than the drift. He (1942) later conceded that the Iowan was an early Wisconsin drift.

For the past two decades existence of the Iowan drift has not been questioned, but an argument has arisen as to its placement in the Wisconsin stage. After formalizing the Farmdale, Leighton and Willman (1950) placed the Iowan as the next younger Wisconsin substage. However, all radiocarbon dates of wood extracted from the drift, that was identified by previous workers as Iowan, were "greater than" values, whereas the Farmdale is dated at 22,000-26,000 years. Accordingly, Ruhe and associates (1957, 1959) proposed and reaffirmed that the Iowan was older than Farmdale, but Leighton (1958, 1960, 1966) objected to this alignment.

The presumed Iowan drift and topography have a number of unique features that are not common to other Wisconsin drifts in Iowa. All of these features have been discussed at length in the voluminous literature on the Iowan and are listed narratively. The features will be discussed where pertinent throughout this paper. Topographic features are: (1) lack of end moraines, (2) extension of sublobes many miles beyond the main drift border down interstream divides,

(3) descendance of undulating and rolling slopes to a region-wide integrated drainage net, (4) occurrence of many areas of isolated topographic highs (paha and inliers) within the Iowan region, (5) directional orientation of longitudinal axes of paha from northwest to southeast, (6) local discordance of trend of paha axes with axis of near sublobe, and (7) lower absolute elevation of Iowan plain where it abuts the older Kansan drift area.

Stratigraphic features are: (1) region-wide occurrence of stone line (pebble band) at top of till where buried by loess or loamy surficial sediment, (2) under thin leached loess, leached zone in subjacent till, (3) under thick calcareous loess, no leached zone in subjacent till, (4) thick loess around border of Iowan in Kansan area, (5) thin loess on Iowan at and for distances behind border, (6) thick loess on paha and inliers, (7) in Kansan area, paleosol between loess and till, (8) in Iowan area, no paleosol between loess and till, (9) in paha and inliers, paleosol between loess and till.

Inferred features are: (1) inheritance of Iowan topography by deposition of thin Iowan drift on dissected Kansan surface, and (2) thin Iowan ice unable to override pre-Iowan topographic highs, i.e., the cores of paha and inliers.

This was the background when the writers began a full-time coordinated geomorphology and soil study in the Iowan area in 1960, and approximately 18 man-years were applied to the work through 1966. Studies are continuing in the region. As the topography of the Iowan area is subdued, few roadcuts are available for examination. Consequently, any stratigraphic research becomes essentially a subsurface study, and drill cores must be employed. If systematic study of drill cores of deposits had been made previously in the Iowan area such study is unknown to us, and herein may be one of the difficulties leading to erroneous previous conclusions in work on the Iowan. The results of our study were presented during the 16th annual field conference of the Midwest Friends of the Pleistocene in 1965 (Ruhe, *et al*, 1965).

Selection of Study Areas

In order to evaluate the previously known topographic and stratigraphic features of the Iowan, the field study areas had to meet five requirements: (1) An area of subdued slopes and low relief on a major divide would most preclude the possibility of post-Iowan erosion. Drill cores to depth in this area would record the most complete stratigraphic record. An area in Palermo Township, Grundy

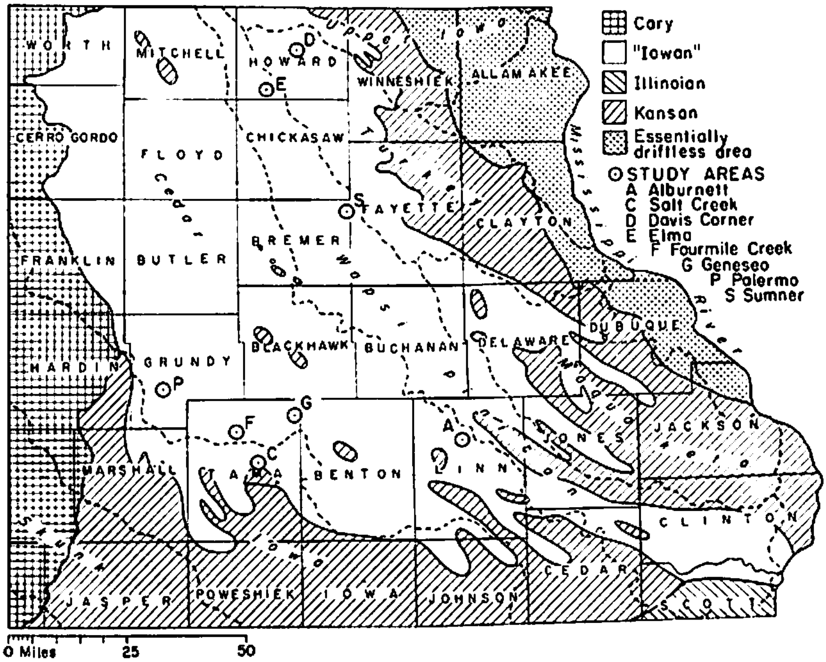

Figure 1. "Iowan drift" of northeastern Iowa from pl. 14, Iowa Geol. Survey Ann. Rept., v. 26, 1917 (cf. Alden and Leighton, 1917). Areas of current study located.

County, (fig. 1) met this requirement as it is on the Iowa-Cedar Rivers divide and is the height of land in the area. Local relief is a few feet to 12 feet in a square mile, and slopes are 0 to 2 percent (fig. 2).

(2) The divide should be continuous and uninterrupted by a valley across country to a paha or inlier. A paha is a loess-capped prominence, elongated as ridges miles in length, or shortened to elliptical hills, that stands apart on the Iowan plain or that merges with similar features to form lengthy ridges or broad plateaus (McGee, 1891). Inliers are large areas of such features. Paha are known to have thick loess overlying pre-Wisconsin paleosols formed in pre-Wisconsin till (Scholtes, 1955). Consequently, by drilling along a continuous divide, the subsurface stratigraphy of the Iowan plain could be traced to a known section in the paha or inlier. The continuous, uninterrupted divide north of Wolf Creek and extending from the Palermo area to the Fourmile Creek inlier in Tama County met this requirement. See figure 1 for location of areas.

(3) Commonly at the previously known Iowan drift border a stream valley separates the Iowan on one side from the Kansan on the

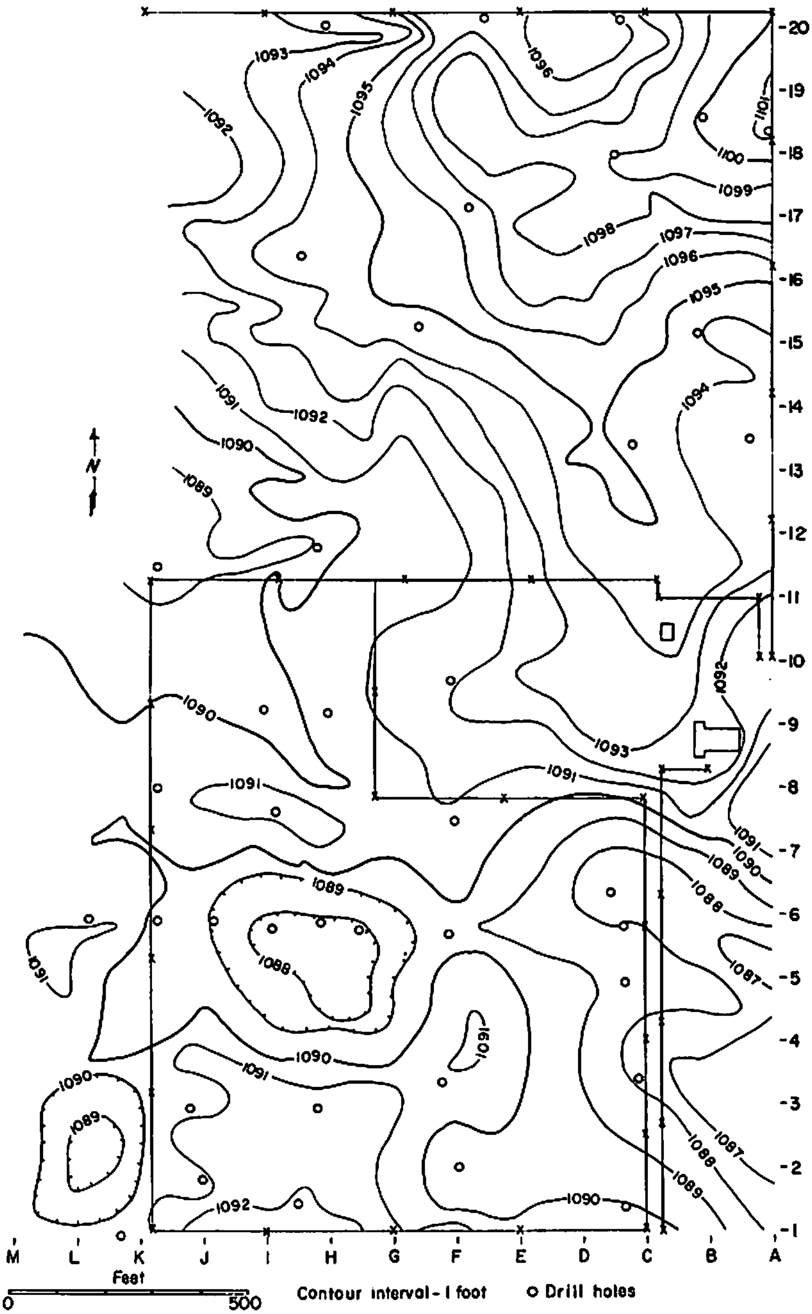

Figure 2. Topography of Palermo Flat, sec. 29, T. 87 N., R. 17 W., Grundy County, showing locations of drill holes.

other. Direct and uninterrupted subsurface stratigraphic tracing is impossible because of the intervening valley. A border area was required where a valley does not separate the Iowan and the Kansan. The Salt Creek area in Tama County qualified (fig. 1).

(4) Another "typical" Iowan landscape has a rolling topography and greater relief than the "Iowan flat" as typified by the Palermo area and a part of the Salt Creek area. A selection was made in Geneseo Township, Tama County, (fig. 1) where slopes are dominantly 3 to 6 percent but with an abundance of slopes of 6 to 16 percent. Maximum relief in the area from Wolf Creek floodplain to the south divide is 186 feet, but locally relief ranges from 20 to 30 feet. In this area paha are the divides to the north and to the south of Wolf Creek. Consequently, the deposits below the Iowan plain could be traced in the subsurface by drilling to the known section of the paha cores.

(5) The desired variation in loess thickness is in these areas. Loess is 35 to 45 feet thick in the Kansan area and on paha. The thickness is 15 to 20 feet in the Palermo area and as thin as 4 to 6 feet in the Geneseo area.

Work has continued in the Alburnett area, Linn County; in the Sumner area, Bremer County; and near Davis Corners and Elma, Howard County (fig. 1).

Subsurface Stratigraphy

Palermo area, Grundy County

The west half of section 29, T. 87 N., R. 17 W., (Palermo Twp.) was drilled in considerable detail[1/]. Continuous cores of loess 2 inches in diameter were extracted with a hydraulic soil-coring machine. At a more compact contact such as till, continuous cores 1¾ inches in diameter were extracted utilizing a split-tube drive sampling tool and a drill rig. The elevations of the tops of all holes were measured and tied to the U. S. Coast and Geodetic Survey net of the area. Elevation measurements in local areas were closed within ±0.5 foot.

Sixteen cores were extracted along the west line of section 29 and an additional 600 feet to the north, and show a uniform mantle of loess 16 to 21 feet thick overlying a till (fig. 3). Twelve of the cores were to shallow depths of 18 to 22 feet, and four of them were to

1/ More detailed treatment than given herein is in Fenton, T. E. (1966). Soils, Weathering Zones, and Landscapes in the Upland Loess of Tama and Grundy Counties, Iowa. Unpublished Ph.D. thesis, Iowa State University, Ames, 327 p.

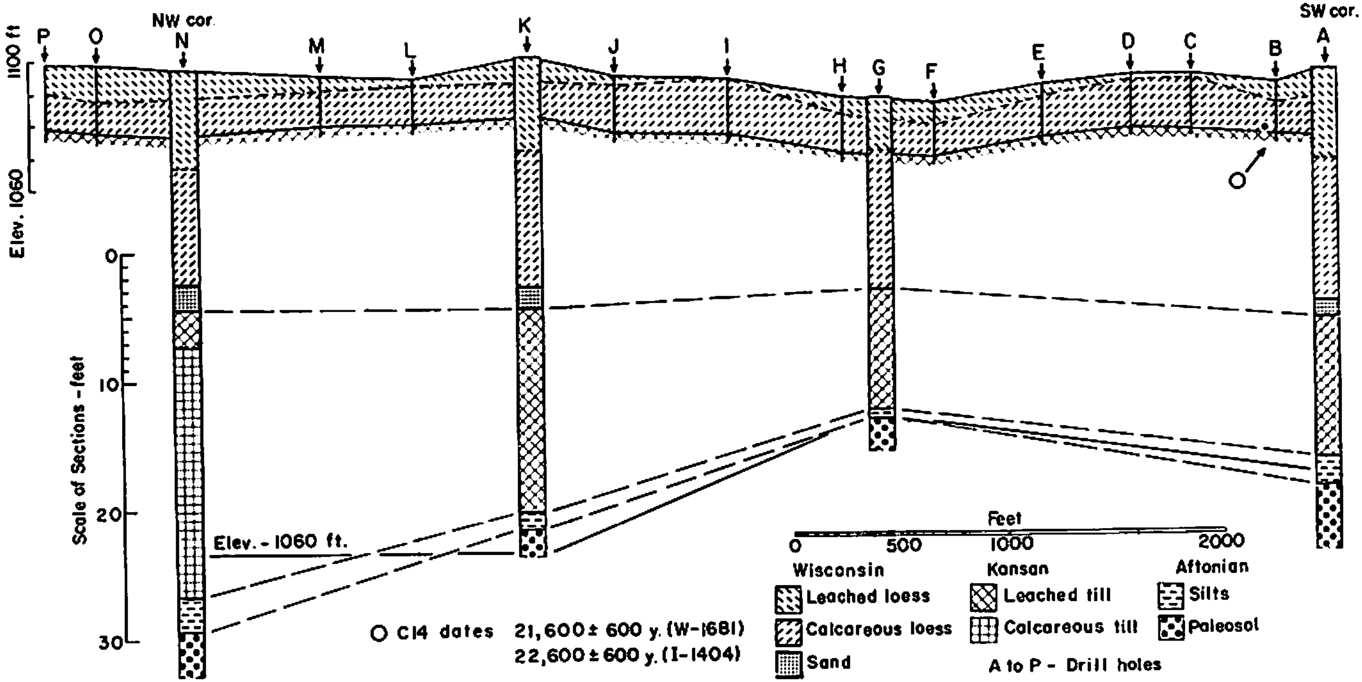

Figure 3. Stratigraphy from drilling traverse along west line sec. 29, Palermo area.

greater depths of 28 to 47 feet. Along this drilling traverse the ground surface is an inherited feature because the constructional loess surface parallels the buried till surface. Both surfaces descend from station A (SW corner of the section) into a valley at station G and ascend to station K toward the NW corner of the section. The valley crossed at station G is a small, tributary near the head of Wolf Creek (fig. 3) and can be traced both in the subsurface and on the ground surface almost half a mile eastward in section 29 where the depression is closed by surface contours 1089 and 1090 (fig. 2: H-M, 8-13). Thus, a drainage net was formed on the till surface, and the till surface was eroded prior to the deposition of loess. Local nonconformance of ground surface to buried till surface further demonstrates these facts. Along the south line and near the center line of section 29, small, shallow, closed depressions are on the constructional loess surface (fig. 2: H-5, L-2). Numerous drillings showed that comparable depressions are not on the subjacent till surface, but that the lower surface descends to the buried valley previously described and to a second buried valley extending to the southeast (fig. 2: D-6). A buried divide is between these two opposing valleys (fig. 2: G-7).

In all drill cores along the west line of section 29, carbonates are leached from the loess from the ground surface to depths of 1 to 11 feet. A subjacent calcareous zone in the loess is 10 to 18 feet thick. Commonly, a dark gray organic zone or number of zones occur in the basal few inches or few feet of the calcareous loess. Organic carbon content of these zones is 0.6 percent, whereas content in the overlying loess generally is 0.1 percent. Organic carbon from the basal 6 inches of the calcareous loess of drill core B (fig. 3) is radiocarbon dated at 22,600 ± 600 years (I-1404) and 21,600 ± 600 years (W-1681)[2/]. More than 95 percent of the loess is younger and is Tazewell in age as the radiocarbon dates are earliest Tazewell time (Ruhe and Scholtes, 1959, p. 592).

In many places a leached, sorted sand 1 to 2 feet thick separates the calcareous loess from the underlying till which, in turn, is *leached* of carbonates to depths of 3 to 16 feet below the top of the till (fig. 3: A, G, K, N). The leached zone, at places, grades downward into calcareous till.

A leached silt bed 1 to 2 feet thick is below the calcareous till and contains zones of organic carbon which is radiocarbon dated at station N (fig. 3) at > 40,000 years (I-1266). The silt overlies a clayey

2/ Radiocarbon laboratories are identified as: I — Isotopes, Inc.; W — U. S. Geological Survey, Washington, D. C.; O — Humble; OWU — Ohio Wesleyan University.

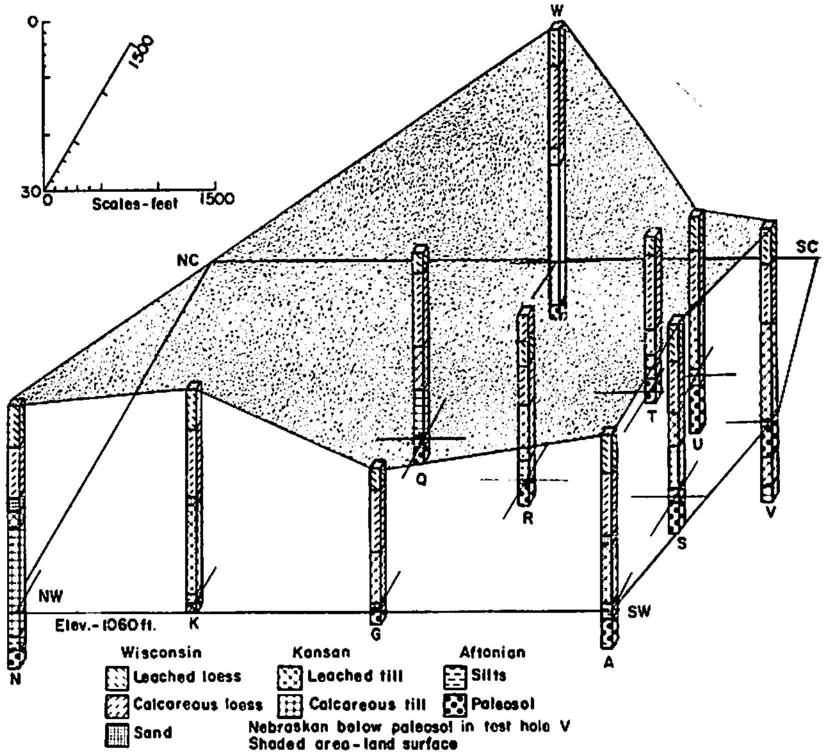

Figure 4. Stratigraphy from areal drilling in west half, sec. 29, Palermo area.

paleosol that is at least 8 feet thick and which is a gumbotil in Pleistocene terminology. The top of the paleosol is at or within a few feet of elevation 1,060 feet above sea level (fig. 3). The same stratigraphic sequence and same deposits were identified in continuous cores at numerous places in the west half of section 29 (fig. 4). In all drill cores leached till is below calcareous loess, and a calcareous zone below the leached till overlies silts and a paleosol. The top of the paleosol at all sites is at or near 1,060 feet above sea level, and the paleosolic surface is essentially a level, flat plain. At station V (fig. 4) the paleosol grades downward into leached till and, in turn, into calcareous till. Thus, in the area there is a second and lower till surmounted by a paleosol with a subjacent leached zone and leaching extends 12 feet below the paleosol surface.

The nature of the deposits, weathering zones, and paleosols of the stratigraphic section are shown by particle-size and carbonate-content distributions to depth in selected cores (table 1). The sand at the base of the loess is shown by the content of the > 62μ size fraction. The upper till has an irregular distribution of sand, silt, and clay. Particularly pertinent is the disorganized distribution of the clay fraction. A paleosolum[3/] was not identified morphologically in the upper part of the upper till in any core. Clay distribution shows no possible pedogenic organization. The silt beneath the upper till has a distinct increase in silt-size particles and decrease in sand. The paleosol at the top of the lower till is indicated by a sharp increase in clay. Leached and unleached zones, obviously, are shown by absence and presence of $CaCO_3$.

Records of two wells at a farmstead at the north center of section 29 show a break from "blue clay" to "yellow clay" at 55- and 60-foot depths. The customary yellow and blue clay parlance of well-drillers generally means oxidized and unoxidized till, respectively. The two farmstead wells are on an upland flat half a mile north of station W (fig. 4) where the top of the paleosol is at a depth of 49 feet. The paleosol in all drill cores is 5 to 9 feet thick and is underlain by oxidized ("yellow clay") and leached till. Thus, the yellow clay in the farmstead wells at 55 and 60 feet probably represents the oxidized and leached zone of the lower till which extends downward to a depth of 90 feet. "Blue clay" (unoxidized till) extends continuously to bedrock at a depth of 160 feet. Consequently, only two tills are probably above bedrock in this area.

In summary, the stratigraphy in section 29 is leached loess overlying calcareous loess, and the whole deposit is less than 21,600-22,600 years old and Tazewell in age. The loess overlies an erosion surface on an upper till that was cut by running water, because the erosion surface descends to buried valleys of a drainage net and has *sorted* sand distributed on it. The upper part of the till is leached of carbonates as much as 16 feet in depth. The fact that *calcareous* loess overlies *leached* till contradicts the generally accepted stratigraphic rule of the Iowan that where loess is thick and calcareous in its lower part, there is no leached zone in the subjacent till. As this rule has been used previously to prove that till, intercalated stone line or sand, and overlying loess were closely related in time, an erosion surface and depth of leaching as great as 16 feet should indicate a hiatus of considerable magnitude. The basic argument between McGee, Calvin, Alden, and Leighton and Kay and associates on the one hand and Leverett on the other hand is involved herein.

3/ A paleosolum is the A and B horizons or parts of them in a paleosol.

Table 1. Properties of Drill Core Samples, Palermo Area

CORE S (Fig. 2, K-1; fig. 4)

Depth (ft.)	Particle Size[1/] Sand-% (>62μ)	Silt-% (62-2μ)	Clay-% (<2μ)	$CaCO_3$ content[2/] (%)
Loess (Tazewell)				
4-5	2.1	72.3	25.6	0.0
6-7	2.3	78.9	18.8	7.5
8-9	4.7	76.7	18.5	20.9
12-13	80.6	14.0	5.4	10.3
13-14	63.1	28.2	8.7	21.7
14-15	4.0	78.5	17.5	19.1
Upper till (Kansan)				
16-17	47.7	30.9	21.4	0.0
18-19	51.0	29.1	19.9	0.0
20-21	48.2	30.4	21.4	0.0
21-22	46.2	31.4	22.4	3.0
22-23	44.3	31.5	24.2	2.2
24-26	27.2	41.2	31.5	3.2
26-27	22.9	47.0	30.0	3.6
27-28.5	19.5	51.8	28.7	—
Silts (pro-Kansan or Aftonian)				
28.5-30	2.7	70.6	26.7	3.1
Paleosol in lower till (Aftonian/Nebraskan)				
31-32	10.6	44.4	44.9	0.0
32-33	14.6	41.7	43.7	0.0
33-34	17.6	38.8	43.6	0.0
36-37	22.0	36.8	41.2	0.0

CORE T (fig. 2, C-6; fig. 4)

Depth (ft.)	Particle Size[1/] Sand-% (>62μ)	Silt-% (62-2μ)	Clay-% (<2μ)	$CaCO_3$ content[2/] (%)
Loess (Tazewell)				
0-1	3.0	63.2	33.8	0.0
1-2	2.2	61.4	36.4	0.0
3-4	5.3	67.5	27.2	2.4
4-5	7.1	76.1	16.8	8.6
6-7	8.1	68.6	23.3	8.9
7-8	3.3	73.9	22.8	12.5
9-10	6.0	76.9	17.1	14.2
10-11	8.9	73.9	17.2	16.0
12-13	7.9	72.2	19.9	15.2
14-15	20.6	47.7	31.7	2.5
Upper till (Kansan)				
15-16	8.7	54.5	36.8	0.0
17-18	17.2	53.4	29.4	0.0
19-20	11.2	57.7	31.0	0.0
20-21	44.9	35.3	19.8	1.0
23-24	43.7	36.9	19.4	6.2
24-25	15.3	60.8	23.9	2.2
26-27	12.5	60.3	27.2	3.1
Paleosol in lower till (Aftonian/Nebraskan)				
27-28	9.1	47.9	43.0	0.0
28-29	12.2	44.6	43.2	0.0

CORE U (fig. 2, C-6; fig. 4)

Depth (ft.)	Particle Size[1/] Sand-% (>62μ)	Silt-% (62-2μ)	Clay-% (<2μ)	$CaCO_3$ content[2/] (%)
Loess (Tazewell)				
0-1	1.6	62.6	35.8	0.0
2-3	2.7	66.7	30.6	0.0
3-4	4.5	74.1	21.4	10.4
5-6	5.6	74.9	19.5	14.6
7-8	4.7	74.2	21.1	12.2
8-9	8.4	74.5	17.1	12.8
Upper till (Kansan)				
16-17	16.6	47.7	35.7	0.0
17-18	13.6	48.6	37.8	0.0
18-19	48.5	28.4	23.0	0.0
19-20	42.9	31.3	25.8	0.0
23-24	12.3	54.0	33.7	0.0
24-25	22.9	44.9	32.2	0.0
Silts (pro-Kansan or Aftonian)				
27-28	1.4	78.2	20.4	0.0
Paleosol (Aftonian)				
28-29	27.4	43.1	29.5	0.0
32-33	19.4	39.2	41.4	0.0
37-38	29.1	33.9	36.9	0.0
Lower till (Nebraskan)				
41-42	44.2	35.7	20.0	7.9

1/ Pipette analysis.
2/ By gravimetric loss of CO_2

In further summary, the upper till is calcareous in its basal part and overlies a silt whose radiocarbon age is > 40,000 years. The silt overlies a lower till that apparently extends to bedrock. This lower till is certainly pre-Wisconsin as it is surmounted by a paleosol at least 8 feet thick, has depths of leaching of carbonates of at least 12 feet, and depths of oxidation of 40 feet. The paleosol at places is gumbotil in Pleistocene terminology.

The lower paleosolic surface is essentially a level, flat plain at or within a few feet of 1,060 feet above sea level. The buried surface of the upper till and its generally paralleling, overlying ground surface on the loess are not level and flat. Instead, they have hills and valleys. Consequently, the previous belief that the Iowan topography is inherited from a deposition of this drift on a dissected buried surface is erroneous.

At this point in the study, the upper till of the Palermo area cannot be classified with certainty. It is pre-Tazewell loess in age and is 22,600 to > 40,000 years old. This does not preclude Iowan because in Iowa the Iowan had been considered older than Farmdale (Ruhe *et al.*, 1957; Ruhe and Scholtes, 1959). However, the occurrence of leached till beneath calcareous loess does not fit the previous criteria of Iowan, and the great depth of leaching and the erosion surface on the upper till suggest that the till is older than Wisconsin.

Palermo area, Grundy County, to Fourmile Creek area, Tama County

In order to determine the identity of the upper till, a drilling traverse was made from the Palermo area along the north divide, the height of land, of Wolf Creek to the Kansan inlier of the Fourmile Creek area. Location of the drill holes in order are: *N'* – NW cor. sec. 29, *O* – SE¼ sec. 20, *N* – NW¼ sec. 27, *M* – NE cor. sec. 35, T. 87 N., R. 17 W., Grundy County; and *L* – center sec. 6, *K* – NW¼ SW¼ sec. 9, J – center NE¼ sec. 15, *I* – SE¼ NE¼ sec. 24, T. 86 N., R. 16 W., Tama County; and *H* – SE¼ NE¼ sec. 19, *G* – EC sec. 20, T. 86 N., R. 15 W., Tama County. Site G is half a mile northwest of the northwest end of a paha ridge of the Fourmile Creek inlier. Along this divide, uninterrupted by valley incision, the land surface descends from 1,096 feet above sea level at site N' to 1,037 feet at site G (fig. 5).

In all but one of these cores, site L, a leached upper till underlies calcareous loess. Depths of leaching range from 1.5 to 14 feet or to an arithmetic mean depth of 5 feet. The till is also oxidized or deoxidized (relict gleying) to depths that range from 3 to 42 feet

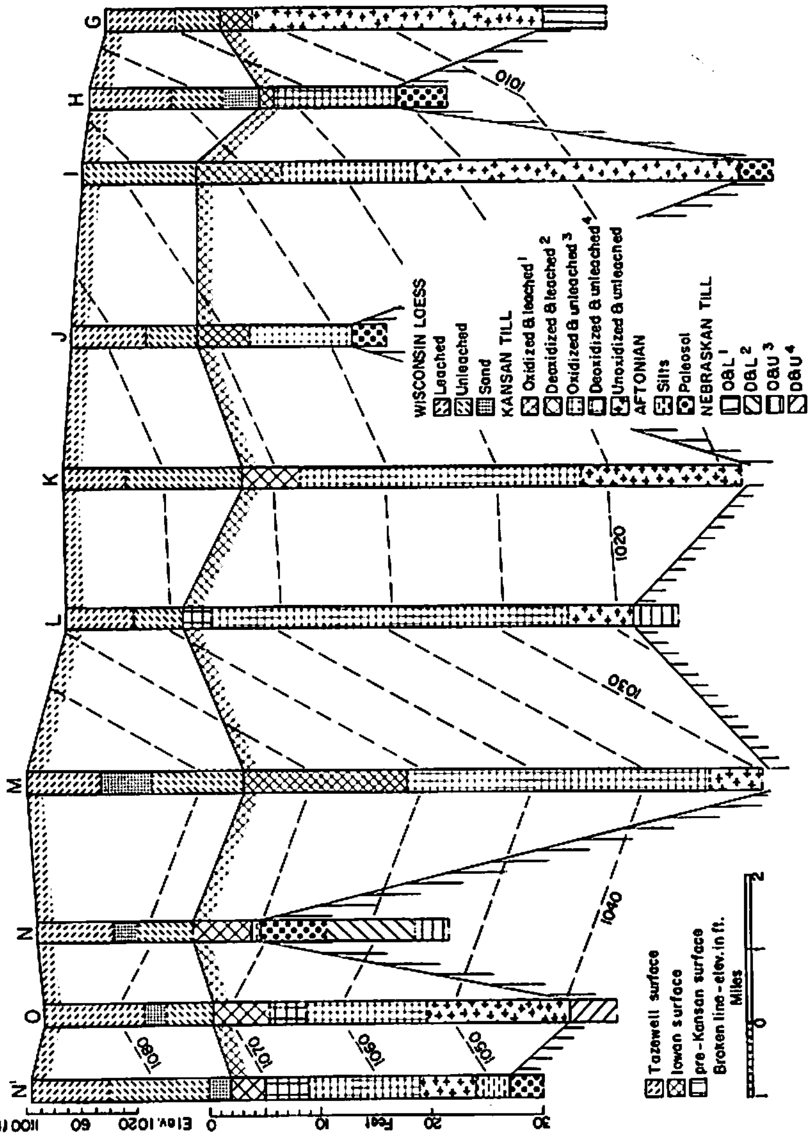

Figure 5. Stratigraphy from drilling traverse from Palermo area to Fourmile Creek area, Tama County.

or an arithmetic mean depth of 20 feet. The lower part of the till, with one exception at site N, is calcareous at all sites. The base of the till rests on silts, clayey paleosol, or another zone of the weathering profile in the lower till (fig. 5). The regional stratigraphy is strikingly similar to the sequence in the Palermo area (cf. figs. 3, 4). The same deposits have been traced across country from Palermo to the Fourmile Creek area.

Along this traverse the basic rule of previous Iowan studies that leached loess overlies leached till or that calcareous loess overlies calcareous till again does not hold. The inferred inheritance of a surface topography from a dissected buried topography does not apply either (fig. 5).

Fourmile Creek area, Tama County

From the last site G of the cross country study, a detailed drilling traverse ascends from the uninterrupted divide to the summit at the northwest end of a paha in the Fourmile Creek area (fig. 6). Here at site 7 the stratigraphy is leached loess over calcareous loess which, in turn, overlies leached till. There is no paleosolum in the upper part of the till. The leached zone grades downward into calcareous till. Leached silts underlie the till and rest on a paleosol with a clayey B horizon which is formed from a lower till. The core at site 7 replicates many of the cores of the Palermo area and many of the cores of the cross country traverse.

Seven cores were extracted in a distance of 1,650 feet as the paha was ascended. Five of the cores were spaced within 350 feet in the critical area of the flank of the paha (fig. 6). At site 6 the stratigraphy of core 7 was duplicated. At site 5 the upper three stratigraphic zones replicated those at sites 6 and 7. The core at site 4 on the paha flank is like the cores of sites 6 and 7. Higher on the flank, core 3 duplicates core 5. At sites 1 and 2 a thick, clayey paleosol intervenes between the calcareous lower part of the loess and the leached zone in the upper till. Beneath the paleosol the leached till grades downward into calcareous till which overlies leached silts and a lower paleosolum. The stratigraphic zones beneath the upper paleosol at sites 1 and 2 replicate the same zones at sites 4, 6, and 7. The stratigraphic zones above the paleosol at sites 1 and 2 replicate the same zones at sites 3, 4, 5, 6, and 7. Thus, the lower paleosol, the intercalated leached silts, and the upper till pass from the lower lying plain into the paha where the upper till is surmounted by a paleosol. These stratigraphic zones are readily identifiable morphologically in particle-size analysis (table 2). The B horizon of the lower paleosol (P2) is brown to dark brown (10YR 4/3)[4/] with strong subangular structure, and clay skins are prominent on the surfaces of soil peds. Clay content ($< 2\mu$) ranges from 34 to 40 percent. The overlying leached silts (LS) are light gray to gray (5Y 6/1) and have dark gray(10YR 4/1) bands of organic matter. Silt content

4/ Munsell soil colors, moist.

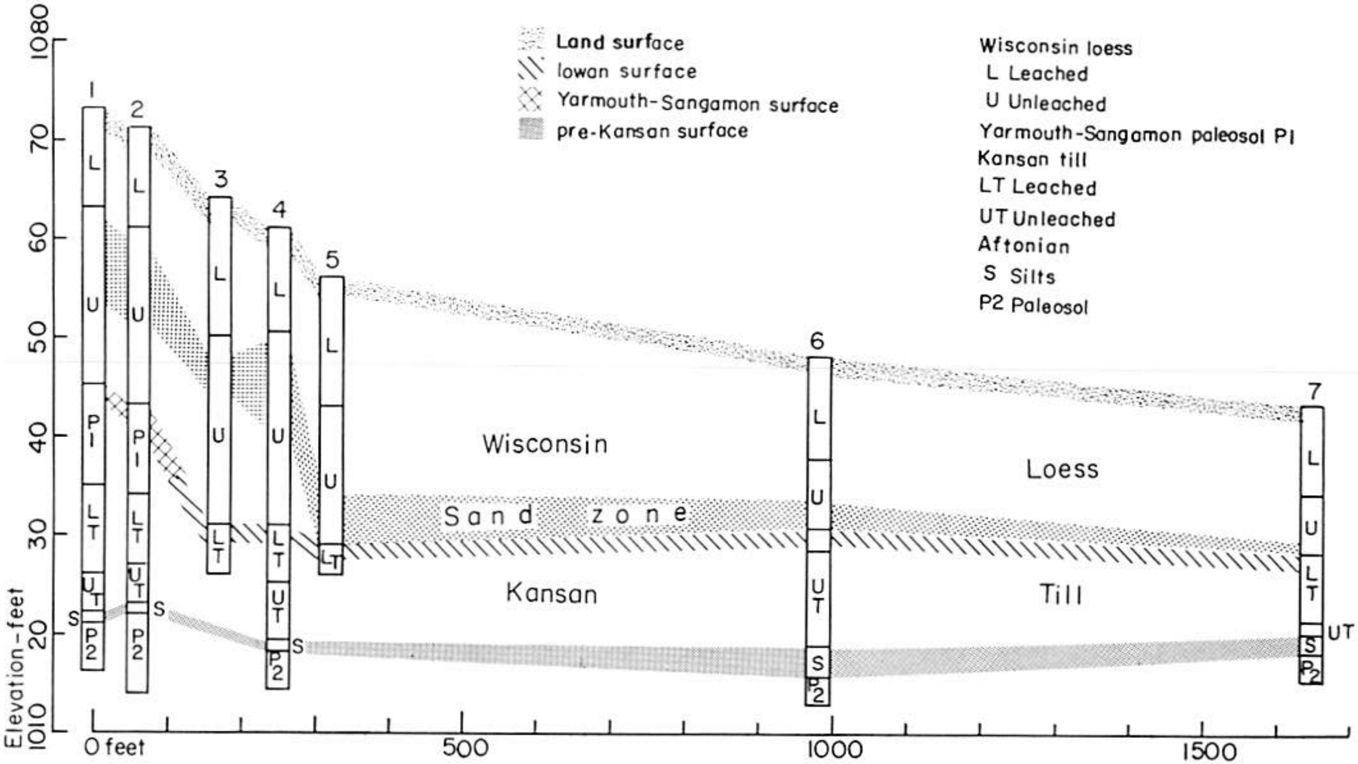

Figure 6. Stratigraphy from drilling traverse from summit of Fourmile Creek paha on to lower adjacent "Iowan" plain.

($62\text{-}2\mu$) ranges from 53 to 76 percent, and the silts are distinctly different texturally from the underlying paleosol and the overlying till (table 2). The paleosol (P1) surmounting the upper till (LT/CT) is 10.5 feet thick, dark gray (5Y 4/1), and heavy textured. Clay content ($< 2\mu$) ranges from 49 to 52 percent. Structure is strong subangular blocky with prominent clay skins on the soil peds. This paleosol is a paleo-Humic Gley soil that is characteristic of the Yarmouth-Sangamon surface of southern Iowa (Ruhe, 1956, p. 445-450) and conforms to the "Kansan gumbotil" of Pleistocene geology terminology of Iowa (Kay and Apfel, 1929, p. 235-241).

There is no morphological evidence in the cores on the paha flank, sites 3 and 4, or on the lower lying landscape, sites 5, 6, and 7, that indicates the presence of a paleosolum in the upper part of the upper till and beneath the calcareous loess. This is substantiated also by the particle-size data from cores 4, 6, and 7 (table 2). The clay ($< 2\mu$) distribution below the upper till contact differs from those of recognizable buried soils such as P1 and P2.

Consequently, beneath the loess of the paha the ridge interior is composed of Yarmouth-Sangamon paleosol, Kansan till, Aftonian silts that contain an A-C horizon paleosol, a more strongly developed Aftonian paleosol with strong B horizon, and Nebraskan till (fig. 6, sites 1, 2). Down the paha flank and onto the lower lying plain, Wisconsin loess buries leached and calcareous Kansan till, Aftonian silts and A-C horizon paleosol, Aftonian paleosol and Nebraskan till. These deposits continue cross country (fig. 5, G to N′) to the Palermo area in Grundy County and are the same there (figs. 3, 4). Although these areas are 15 to 20 miles north of the presumed Iowan drift border of previous workers (fig. 1), Iowan drift does not exist. Instead, there is a widespread erosion-surface complex that is cut in Kansan till and older deposits. This erosion surface complex is marked by a stone line (Ruhe, 1959) that is the "Iowan pebble band" of previous workers. Erosion stripped the Yarmouth-Sangamon and other pre-Wisconsin paleosols, and various weathering zones of the Kansan till and older deposits. The erosion-surface complex is named here as the *Iowan surface*. It is a subaerially evolved feature and glacier ice is unequivocally precluded from any association with it. The surface is mantled by Wisconsin loess.

The paha interiors of paleosols and tills are erosion remnants standing above the Iowan surface at interstream divides. The erosion remnants are buried by thicker loess than that on the lower lying Iowan surface.

Table 2. Particle-Size Analysis and Stratigraphy of Cores at Fourmile Creek

CORE NO. 1

Depth (ft.)	Particle Size* Sand-% (>62μ)	Silt-% (62-2μ)	Clay-% (<2μ)	Unit
0-1.5	1.3	71.2	27.5	LL
1.5-2.8	1.4	75.7	22.9	LL
2.8-3.6	0.9	78.5	20.6	LL
3.6-5.4	2.2	84.3	13.5	LL
5.4-8.5	4.3	80.2	15.5	CL
8.5-11.3	6.2	78.5	15.3	CL, SZ
11.3-12.5	10.3	74.5	15.3	CL, SZ
12.5-14.1	20.0	64.4	15.6	CL, SZ
14.1-14.5	26.6	59.4	14.0	CL, SZ
14.5-15.4	11.4	74.5	14.1	CL, SZ
15.4-15.7	25.4	61.1	13.5	CL, SZ
15.7-16.5	7.4	78.3	15.3	CL, SZ
16.5-19.1	1.8	83.5	14.7	CL
19.1-21.9	1.6	84.3	14.1	CL
21.9-24.7	1.7	82.5	15.8	CL
24.7-25.4	2.2	86.9	10.9	LL
25.4-26.2	1.6	48.3	50.1	P1
26.2-26.9	2.0	48.0	50.0	P1
26.9-27.9	1.5	46.6	51.9	P1
27.9-28.9	3.9	47.2	48.9	P1
28.9-29.9	3.4	48.0	48.6	P1
29.9-31.9	5.6	42.3	52.1	P1
33.9-35.9	16.0	35.3	48.7	P1
37.9-39.9	45.5	28.9	25.6	LT
42.0-42.8	48.4	29.3	22.3	LT
42.8-43.6	47.0	30.8	22.2	CT
43.6-45.0	18.4	62.4	19.2	LS
45.0-46.8	10.9	66.6	22.5	LS
46.8-47.4	27.5	39.2	33.3	P2
47.4-48.0	33.5	32.7	33.8	P2

CORE NO. 4

Depth (ft.)	Particle Size Sand-% (>62μ)	Silt-% (62-2μ)	Clay-% (<2μ)	Unit
0-2.0	1.6	71.1	27.3	LL
2.0-6.0	1.0	75.6	23.4	LL
6.0-6.4	1.1	82.4	16.5	LL
6.4-8.0	0.9	79.5	19.6	LL
8.0-12.6	8.4	74.8	16.8	CL, SZ
12.6-15.6	14.4	70.9	14.7	CL, SZ
15.6-18.0	27.3	57.4	15.3	CL, SZ
18.0-22.0	2.4	79.1	17.9	CL
22.0-26.5	3.5	72.1	24.4	CL
26.5-27.5	53.5	18.8	27.7	LT
27.5-28.0	45.0	27.6	27.4	LT
28.0-29.8	62.9	17.8	19.3	LT
29.8-31.0	47.0	32.5	20.5	LT
31.0-31.9	43.3	34.2	22.5	LT
31.9-32.7	44.2	30.5	25.3	LT
32.7-35.0	44.9	34.7	20.4	CT
35.0-35.7	45.4	34.4	20.2	CT
35.7-37.0	45.9	34.1	20.0	CT
37.0-38.5	25.5	52.8	21.7	LS
38.5-39.0	43.7	34.8	21.5	P2
39.0-41.0	24.9	38.7	36.4	P2

CORE NO. 6

Depth (ft.)	Particle Size Sand-% (>62μ)	Silt-% (62-2μ)	Clay-% (<2μ)	Unit
0-1.5	1.3	66.0	32.7	LL
1.5-3.3	1.6	68.9	29.5	LL
3.3-4.0	1.2	71.7	27.1	LL
4.0-6.0	1.1	73.6	25.3	LL
6.0-8.0	1.1	78.9	20.0	LL
8.0-9.0	1.3	81.5	17.2	CL
9.0-10.2	1.6	80.8	17.6	CL
10.2-11.8	1.1	81.8	17.1	CL
11.8-14.4	6.3	75.7	18.0	CL, SZ
14.4-14.9	47.3	35.6	17.1	LT
14.9-15.3	48.7	35.4	15.9	LT
15.3-16.0	39.5	42.5	18.0	LT
16.0-16.5	22.9	57.4	19.7	LT
16.5-17.0	25.1	52.3	22.6	CT
17.0-18.4	57.1	27.5	15.4	CT
18.4-20.0	45.2	34.5	20.3	CT
20.0-22.0	44.6	34.1	21.3	CT
22.0-24.0	34.8	37.0	28.2	CT
24.0-26.0	35.3	40.2	24.5	CT
26.0-29.1	1.6	76.4	22.0	LS
29.1-29.7	14.3	59.9	25.8	P2
29.7-31.0	20.6	45.9	33.5	P2

CORE NO. 7

Depth (ft.)	Particle Size Sand-% (>62μ)	Silt-% (62-2μ)	Clay-% (<2μ)	Unit
0-1.0	1.1	64.1	34.8	LL
1.0-2.7	0.8	62.4	36.8	LL
2.7-5.3	1.1	73.6	25.3	LL
5.3-7.0	1.5	82.1	16.4	CL
7.0-7.3	1.9	83.8	14.3	CL
7.3-12.8	1.6	80.0	18.4	CL
12.8-14.5	2.1	79.0	18.9	CL, SZ
14.5-14.9	58.4	24.1	17.5	LT
14.9-15.4	46.6	30.1	23.3	LT
15.4-17.0	38.1	33.2	28.7	LT
17.0-18.0	46.5	29.0	24.5	LT
20.0-22.5	31.4	42.0	26.6	CT**
22.5-23.3	1.4	73.8	24.8	LS
23.3-24.6	3.4	68.0	26.6	LS
24.6-25.3	16.4	43.9	27.5	P2
25.3-26.0	16.6	56.1	39.5	P2

* Modified Wentworth Classification.

** Till is calcareous from 21 ft. 10 in. to 22 ft. 5 in.

Symbols: SZ - sand zone; LL - leached loess; CL - calcareous loess; P1 - upper paleosol; LT - leached till; CT - calcareous till; LS - leached silts; P2 - lower paleosol.

An erosional explanation of the paha interior and lower plain is simpler and better based on fact than the previous explanation of paha origin (Scholtes, 1955) that Iowan ice did not override the pre-Wisconsin topographic high but moved around it and deposited Iowan till against the flanks of the ridge. An erosion explanation also dispels conflicting previous ideas about Iowan glaciation such as: (1) thin ice not overriding slight topographic highs but (a) extending sublobes many miles beyond the main drift border, and (b) extending sublobes down interstream divides but not down valleys (fig. 1). Erosional origin also explains better: (1) lack of end moraines on the "Iowan drift surface," (2) descendance of undulating or rolling slopes to a region-wide integrated drainage net, (3) the occurrence of many areas of isolated topographic highs (paha and inliers), (4) lower absolute elevation of the Iowan surface where it abuts the older Kansan drift, and (5) region-wide occurrence of a stone line (Iowan pebble band) at the top of till where it is buried by loess or loamy surficial sediment.

Fourmile Creek area to Salt Creek area, Tama County

Fourmile Creek joins Wolf Creek in sec. 7, T. 85 N., R. 14 W., Tama County. Wolf Creek drains to Cedar River at LaPorte City, Black Hawk County. To the south of the Fourmile and Wolf Creek junction is Salt Creek which drains to the Iowa River at the southeastern corner of Tama County. Thus, the area between Wolf and Salt Creeks is a major divide between the Cedar and Iowa Rivers. The upland marked by the divide continues around the head of Salt Creek and extends to the presumed Iowan-Kansan border in the northwest part of T. 84 N., R. 14 W., Tama County. Here, the requirement was met that a valley not intervene between the Iowan and Kansan so that uninterrupted subsurface stratigraphic tracing would be possible.

Numerous cores extracted on the broad upland between Wolf and Salt Creeks replicate the basic shallow stratigraphy of the Palermo area and the regional traverse to the Fourmile Creek paha (fig. 7). For example, in the NE¼ sec. 28, T. 85 N., R. 15 W., 6 feet of leached loess overlies 2 feet of calcareous loess and 7 feet of leached till. No paleosolum is in the upper part of the till. This site is north of an isolated paha that is astride U. S. Highway 63. South of the paha in the SW¼ sec. 3, T. 84 N., R. 15 W., 5 feet of leached loess overlies 4 feet of calcareous loess and 4 feet of leached till with no intervening paleosol. Other borings show the same relationship (fig. 7). So, the same shallow stratigraphic sequence holds from the Palermo area to the presumed Iowan-Kansan border in the Salt Creek area.

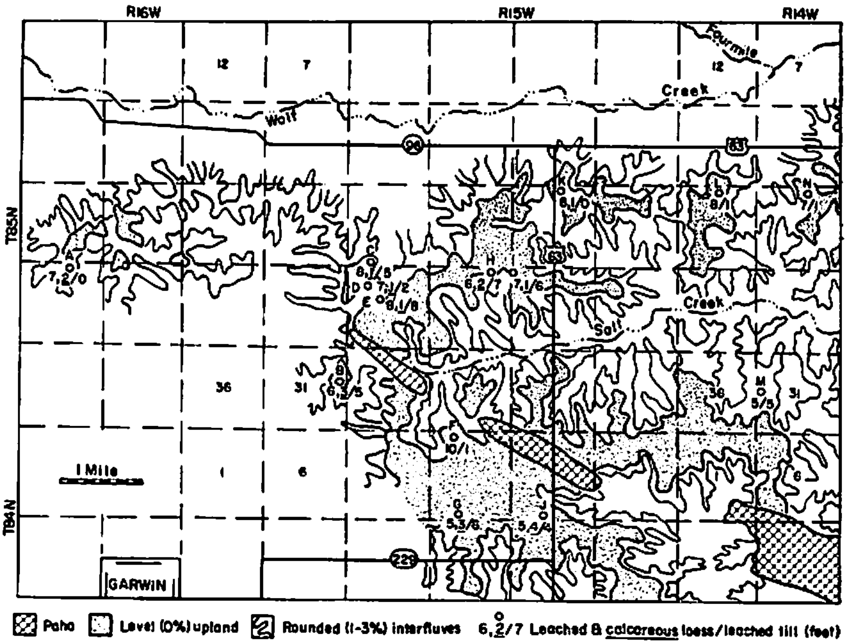

Figure 7. Areal drilling data and locations from Fourmile Creek area to Salt Creek area, Tama County.

Salt Creek border area

The Iowan landscape directly abuts the Kansan landscape and stands 50 feet lower (fig. 8). Three detailed drilling traverses were made across the border, but because they are repetitive, only parts of these traverses are discussed herein[5/]. In all traverses the stratigraphy in cores replicates the relationships at Fourmile Creek (fig. 6).

On the lower lying Iowan landscape, leached loess overlies calcareous loess which, in turn, mantles leached and then calcareous till. These horizons were traced, for example, on one traverse, through 15 closely spaced drilling sites across the Kansan border and on to the Kansan landscape (fig. 8). One till passes from the Iowan area and beneath a paleosol that is 13.5 feet thick (table 3) in the Kansan area. Thus, in this area also there is no separate and distinct younger till abutting the Kansan. Instead, and as at Fourmile Creek, the lower lying landscape is a loess-mantled erosion surface that is cut into

5/ More detailed treatment is in Hall, G. F. (1965). Geomorphology and soils of the Iowan-Kansan border area, Tama County, Iowa, Unpublished Ph.D. thesis, Iowa State University, Ames, 286 p.

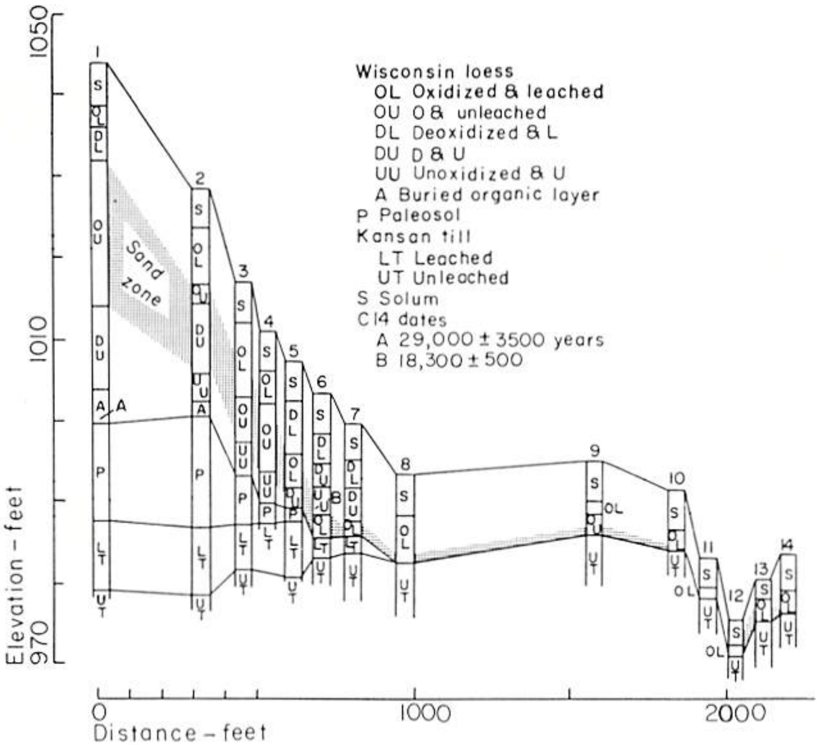

Figure 8. Stratigraphy in Salt Creek area from drilling traverse from Kansan area across presumed Iowan border on to Iowan area.

Kansan till and from which the thick Yarmouth-Sangamon paleosol has been stripped. The stone line ("Iowan pebble band") on Kansan till commonly marks the erosion surface.

Radiocarbon dates in organic zones at the base of the loess demonstrate the age of formation of the erosion surface. At site 1 (fig. 8) organic-carbon content of the basal buried A horizon ranges from 1.6 to 3.5 percent in the zone that is 6 to 20 inches above the top of the Yarmouth-Sangamon paleosol. The organic carbon is 29,000 ± 3,500 years old (I-1269) and is buried under 44 feet of younger loess.

At site 6 (fig. 8) organic carbon at the base of the calcareous loess is 18,300 ± 500 years old (W-1687). This zone overlies 2 feet of sand which, in turn, lies on the Iowan erosion surface. There is no paleosolum in the upper part of the till at site 6, indicating that burial of the erosion surface by sand and calcareous loess followed soon after its cutting and prevented soil formation.

Table 3. Particle-Size Analysis, Carbonate Content, and Stratigraphy of Cores at Salt Creek

CORE ON KANSAN LANDSCAPE

Depth (ft.)	Particle size: Sand - % (>62μ)		Particle size: Silt - % (62-2μ)	Particle size: Clay - % (<2μ)	$CaCO_3$ equiv. (%)	
0-0.58	1.2		70.2	28.6	0.0	
0.58-1.17	0.8		69.9	29.3		
1.17-1.58	0.8		69.0	30.2		
1.58-1.92	0.8		68.9	30.3		
1.92-2.17	0.7		69.4	29.9		
2.17-2.67	0.6		67.7	31.7		
2.67-3.08	1.2		64.0	34.8		
3.08-3.67	1.2		66.7	32.1		
3.67-4.17	1.0		70.6	28.4		LL
4.17-4.75	1.0		70.0	29.0		
5.4-6.0	1.2		76.6	22.2		
6.5-7.0	5.1		72.8	22.1		
7.5-8.0	3.4		77.6	19.4		
8.5-9.0	2.3		77.1	20.6		
9.5-10.0	3.0		76.4	20.6		
10.5-11.0	20.9		61.8	17.3	0.0	
11.5-12.0	25.7		58.1	16.2	6.8	
12.0-12.5	14.8	SZ	67.6	17.6	7.4	
12.5-13.0	12.6		69.8	17.6	—	CL
14.5-15.0	43.9		41.5	14.6	3.1	
15.5-16.0	1.8		77.9	20.3	4.0	
16.5-17.0	0.8		78.9	20.3	3.1	
17.5-18.0	0.9		68.2	30.9	0.3	LL
18.5-19.0	1.3		57.1	41.6	0.0	
19.0-19.5	1.6		60.5	37.9	0.0	
19.5-20.0	1.7		55.5	42.8	0.0	P1
20.0-24.0	2.9		43.2	53.9	0.0	
24.0-28.0	10.4		41.8	47.8	0.0	
28.0-32.0	10.8		44.3	44.9	0.0	
39.0-43.0	40.6		37.2	22.2	17.5	CT

CORE ON IOWAN LANDSCAPE

Depth (ft.)	Particle size: Sand - % (>62μ)		Particle size: Silt - % (62-2μ)	Particle size: Clay - % (<2μ)	$CaCO_3$ equiv. (%)	
0-0.4	1.1		69.5	29.4	0.0	
0.4-0.75	1.1		67.3	31.6		
0.75-1.08	1.0		64.2	34.8		
1.08-1.42	1.0		62.4	36.6		
1.42-1.67	0.9		63.0	36.1		
1.67-1.83	1.0		63.5	35.5		
1.83-2.17	1.2		65.4	33.4		
2.17-2.58	1.3		67.9	30.8		LL
2.58-3.00	1.1		69.0	29.9		
3.00-3.42	1.2		72.4	26.4		
3.42-3.83	1.1		71.9	27.0		
3.83-4.17	0.7		72.3	27.0		
4.58-5.00	0.9		71.5	27.6		
5.5-6.0	1.1		71.9	27.0	0.0	
6.5-7.1	1.7		76.4	21.9	4.7	
7.7-8.0	2.4		79.0	18.6	9.0	CL
8.0-8.4	1.6		73.8	24.6	2.7	
8.8-9.2	49.3	SZ	34.4	16.3	3.0	CS
9.2-9.5	43.9		34.2	21.9	1.6	LT
9.5-10.0	46.8		33.4	19.8	6.8	
10.5-11.0	46.5		34.5	19.0	10.8	CT
11.5-12.0	41.4		37.5	21.1	9.9	

Symbols: SZ - sand zone; LL - leached loess; CL - calcareous loess; CS - calcareous sand; P1 - upper paleosol; LT - leached till; CT - calcareous till.

Consequently, the Iowan erosion surface at Salt Creek formed between 29,000 and 18,300 years ago, because the older value dates the buried, higher standing old land, and the younger value dates the buried, lower lying erosion surface. Maximum age of cutting could be considerably less than 29,000 years. Sand related to the erosion surface at site 6 is traceable through sites 5, 4, 3, 2, and to site 1 and rises high in the loess at site 1, indicating a contemporaneity of the uppermost 10 to 15 feet of loess at all sites (see table 3 for data of comparable site). At site 1 a considerable thickness of relatively sand-free loess underlies the sand zone, indicating that for some time after 29,000 years, the erosion surface had not been formed, so that a source of sand was not available for incorporation in the loess. Note further, that a low-sand content paleosol intervenes between the loess and loamy till.

Similar textural zones are in the loess at Fourmile Creek (table 2; fig. 6). There at site 6, sand immediately overlies the Iowan erosion surface on loamy till. However, at site 4 the sand zone in loess is from 8 to 18 feet in depth, with relatively sand-free loess to a depth of 26.5 feet. At site 1, 9 feet of relatively sand-free loess underlies the sand zone which extends from 8.5 to 16.5 feet in depth. Note further that a low-sand content paleosol intervenes between the loess and loamy till.

Regardless of the absolute maximum age of cutting of the erosion surface, the dates extend from earliest Farmdale well into Tazewell time of the midcontinent Pleistocene (Ruhe and Scholtes, 1959). The ages of the surface in the Palermo area, 22,600 ± 600 and 21,600 ± 600 years, also fall within this range.

Geneseo area

In this area in Tama County, the landscape rises in a series of stepped levels away from Wolf Creek toward bounding divides. To the south the divide is Hayward's paha and to the north it is Casey's paha. An 85-foot drilling on Hayward's paha penetrated 36 feet of Wisconsin loess, 10 feet of paleosol on Kansan till, 5 feet of leached Kansan till, 8 feet of paleosol on Nebraskan till, 16 feet of leached Nebraskan till, and 10 feet of calcareous Nebraskan till (fig. 9, site 1). Along a drilling traverse to the north through nine sites, the subsurface stratigraphy shows again that the lower adjacent landscape, sites 6 to 9, is cut in Kansan and *Nebraskan* till. The lower landscape was considered to be the Iowan. No identifiable till of Wisconsin age abuts Hayward's paha.

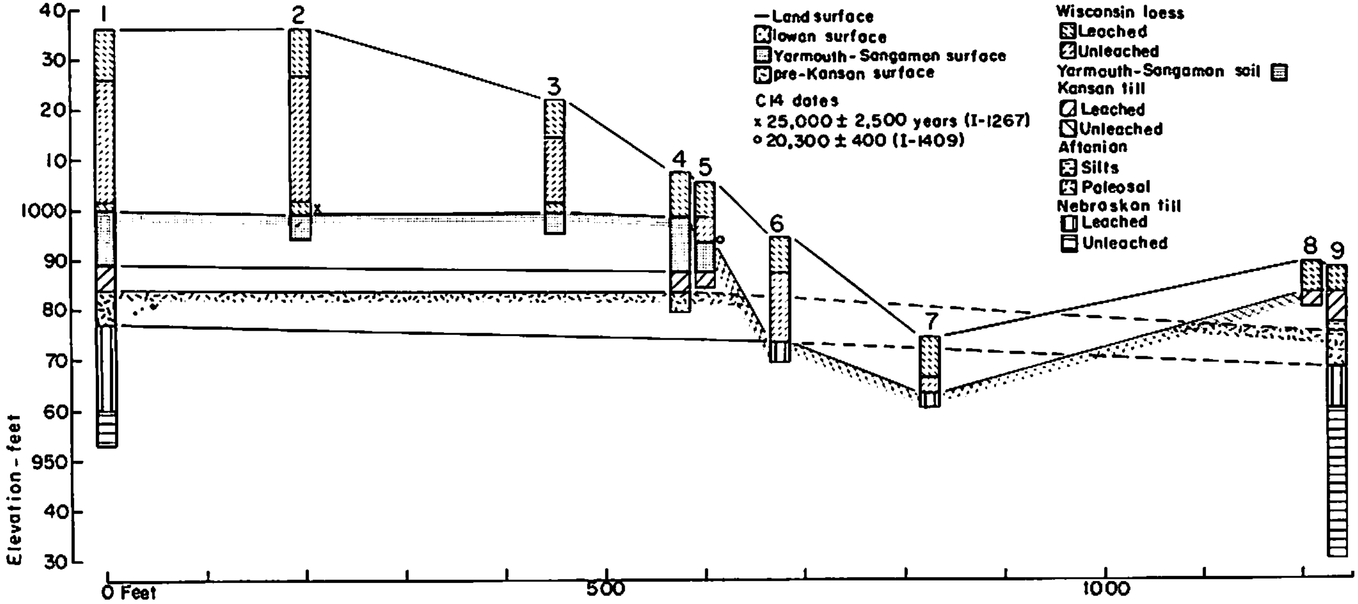

Figure 9. Stratigraphy in Geneseo area from drilling traverse from summit of Hayward's paha on to lower adjacent "Iowan" plain.

A drilling net of 19 sites on Casey's paha north of Wolf Creek shows similar stratigraphy (Ruhe *et al.*, 1965, p. 19-20). The lower lying landscape on the north side of Casey's paha is a surface cut in Kansan and Nebraskan till. No identifiable till of Wisconsin age abuts this paha either.

Radiocarbon dates at Hayward's paha define the time of cutting of the lower erosion surface. The base of the loess on the Yarmouth-Sangamon paleosol in the paha is 25,000 ± 2,500 years old (I-1267). The erosion surface that truncates the paleosol and subjacent till, Aftonian paleosol, and Nebraskan till is dated at site 5 (fig. 9) at 20,300 ± 400 years (I-1409). These dates neatly fall in agreement with the dates at Palermo and Salt Creek.

Alburnett area, Linn County

In this area the Iowan drift also was presumed to abut and surround inliers and paha (fig. 1). A drilling traverse from the summit of the paha down its northern flank on to the lower lying plain (fig. 10) negates occurrence of the Iowan here also.

On the summit at ground level of 975 feet, 44 feet of Wisconsin loess whose lower 30 feet are calcareous, overlies a greenish-gray Kansan till that is leached of carbonates for 2 feet. No paleosolum is in the top of this till. An additional 12 feet of Kansan till is calcareous and overlies at least 5 feet of leached Nebraskan till. The contact between tills is at an elevation of 918 feet. A drill hole on the shoulder of the paha penetrated 12.5 feet of leached Wisconsin loess, 17 feet of calcareous Wisconsin loess, 3.5 feet of calcareous sand, and 2.5 feet of calcareous Kansan till. A paleosol 9 feet thick underlies the calcareous till and, in turn, is on 5 feet of leached Nebraskan till. The upper till-paleosol contact is at an elevation of 917 feet and in excellent agreement with the contact elevation at the summit site.

A drill hole on the north slope of the paha penetrated 17 feet of sandy, leached Wisconsin loess, 14 feet of calcareous loess, and 3 feet of sand. At an elevation of 904 feet in the hole, leached till continues to depth. This leached till is Nebraskan as its leached zone in the shoulder site is below an elevation of 910 feet. Consequently, the lower lying plain to the north of the paha (fig. 10) is cut in Nebraskan till. No Iowan drift is present.

The stratigraphy of the paha summit site is like that at Palermo, and a radiocarbon date from the base of the loess on the summit is 20,700 ± 500 years (I-2332). This is in excellent agreement in time with the dates at Palermo.

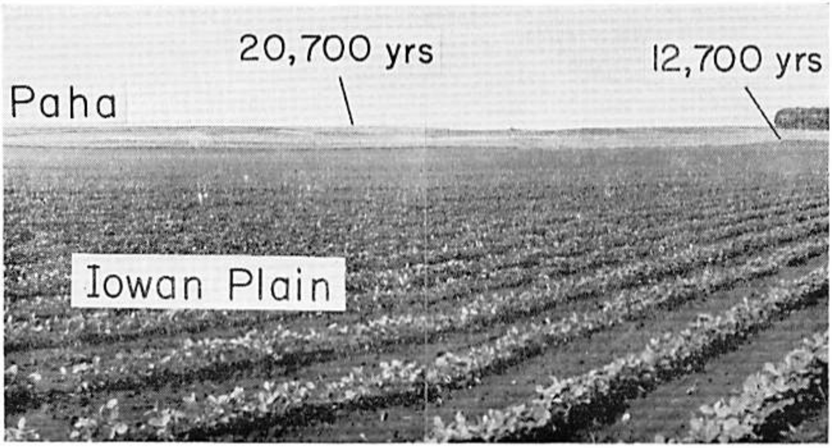

Figure 10. Landscape at Alburnett paha, Linn County, locating drilling sites and radiocarbon dating locations (see text).

At the base of the north slope of the paha (fig. 10), 10 feet of alluvial fan sediment, derived from a drainageway on the paha, buries a mucky peat whose age is 12,700 ± 290 years (I-2333). Thus, the lower lying erosional plain on Nebraskan till is less than 12,700 years old. This surface, too, was the Iowan of previous workers. It is devoid of loess but has thin loam sediments mantling an almost continuous stone line. The loess had to be eroded, and the erosional date of 12,700 years fits the chronology of loess deposition in Iowa which terminated 14,000 years ago (Ruhe, 1965, p. 118).

A continuous core to bedrock shows that only one till, the Nebraskan, is present.

Davis Corners area, Howard County

A number of deep drillings in this area replicated the stratigraphy below the low-lying surface around the paha in the Fourmile Creek, Geneseo, and Alburnett areas and the flat country of the Palermo area. A major difference is the lack of loess mantling the uppermost till. However, the lack of a continuous loess mantle is a common feature on the Iowan surface north of a line that extends from Cerro Gordo County southeastward through Butler, Black Hawk, Benton, and Linn Counties. In place of the loess, loam sediments a few feet thick overlie a stone line on till.

In the NW¼ sec. 30, T. 99 N., R. 12 W., 3 feet of leached loam sediments overlies a stone line on an upper till. The till is leached of carbonates for 3 feet and is calcareous for an additional 32 feet. At a depth of 38 feet, the till abruptly overlies silts containing organic carbon which, in turn, overlie 5 feet of leached lower till that then is calcareous to depth. A second deep drilling completely penetrated the lower till to shale bedrock. Only two tills are in the area. Organic carbon from the silts interbedded between the two tills is radiocarbon dated at >39,900 years (I-2331). The till-silt-till stratigraphy and the radiocarbon date is a replicate of the Palermo sequence. There is no evidence for Iowan till here either, and the two tills are Kansan and Nebraskan.

Iowan Surface

Morphometry

The subsurface stratigraphy of the study areas demonstrates absolutely that Iowan till does not exist but that an erosion-surface complex does exist in the Iowan region. The interior ridges of paha and inliers that are mantled by loess are erosion remnants of the Yarmouth-Sangamon surface, the Late Sangamon surface, or a part of the Iowan surface itself. The erosion remnants are on interstream divides and the Iowan erosion-surface complex encroached on these remnants from all directions. They stand isolated above a lower lying, multi-leveled plain. This, then is the genetic nature of the paha and inliers and the previous hypotheses of their origin (Scholtes, 1955) are negated.

The magnitude of erosion can be measured where detailed studies have been completed. At the extreme limit of the drainage net on the Iowan surface at Fourmile Creek (fig. 6), a level of the surface is cut to a mean depth of 14.5 feet below the remnantal Yarmouth-Sangamon surface that is preserved within the paha. In the border area at Salt Creek (fig. 8), a level of the Iowan surface is cut to a mean depth of 15.7 feet below the remnantal Yarmouth-Sangamon surface that is preserved beneath the loess on the south side of the border.

The Iowan surface is multi-leveled and is arranged in a series of steps from major drainages toward bounding divides. Treads and risers repeat themselves along interfluves from Wolf Creek southward to the bounding divide of Hayward's paha. From Wolf Creek, whose elevation is 840 feet, three floodplain and terrace levels that are loess-free parallel the creek. A loess-mantled higher terrace at 855 feet is 15 feet above the stream. Two higher steps then occur between the high terrace and the loess-mantled paha, and the lower tread ascends from 893 to 979 feet in a distance of 1.2 miles, and the upper tread ascends from 986 feet to 996 feet in half a mile. The summit of the paha is at 1,036 feet. The Iowan erosion-surface complex on the pre-loess deposits rises on the lower tread from 890 to 973 feet and on the upper tread from 979 to 988 feet. Where the paha is abutted, the Yarmouth-Sangamon surface in the paha is at 1,000 feet. Thus, the Iowan surface is cut from 12 to 110 feet below the erosion remnant in 1.7 miles and progressively truncates downward Yarmouth-Sangamon paleosol, Kansan till, Aftonian silts, Aftonian paleosol, and Nebraskan till.

At the northwest end of Casey's paha on the divide north of Wolf Creek the Iowan surface is 15 feet below the Yarmouth-Sangamon paleosol that is preserved in a road cut along defunct state highway 402. Here the surface is cut on Kansan till, and its elevation is 1,002 feet, compared to 1,017 feet for the top of the paleosol. At the east end of the paha the Iowan surface is as much as 30 feet below the Late Sangamon surface that is preserved in a road cut along the Tama-Benton County line road. The top of the paleosol is at 952 feet, and the Iowan surface descends across Kansan and Nebraskan tills to an elevation of 922 feet (Ruhe *et al.*, 1965, p. 19-20).

At Alburnett paha the top of the eroded, leached Kansan till is buried by loess in the paha and is at an elevation of 931 feet. Ground level at the fence north of the paha is 900 feet (fig. 10). If 10 to 12 feet, the normal thickness of a Yarmouth-Sangamon paleosol, is added to the till in the paha, the Iowan surface is cut 41 to 43 feet below the top of the paleosol and across Kansan and Nebraskan till.

The Iowan surface is marked where it cuts Kansan and Nebraskan tills by a stone line (Iowan pebble band of previous literature). The stone line occurs on all levels of the stepped surfaces where they occur and descends slopes and passes under alluvium along the drainageways of the well-integrated drainage net of the region. South of the line from Cerro Gordo to Benton and Linn Counties, loess with interbedded, mixed, or basal sand overlies the stone line. But north of the line, thin loam sediments generally overlie the stone line.

Age

The age of the Iowan surface is directly determinable by radio-carbon dating. At Salt Creek (fig. 8) the remnantal Yarmouth-Sangamon surface was buried by loess at 29,000 ± 3,500 years

(I-1269). The Iowan surface was cut and buried beneath loess at 18,300 ± 500 years (W-1687). Here the surface is 18,300 to 29,000 years old.

At Hayward's paha (fig. 9) the remnantal Yarmouth-Sangamon surface was buried by loess at 25,000 ± 2,500 years (I-1267). The Iowan surface was cut and buried by loess at 20,300 ± 400 years (I-1409). At Palermo (fig. 3) the Iowan surface was cut and buried by loess at 22,600 ± 600 years (I-1404) and 21,600 ± 600 years (W-1681).

In order to emphasize the values of the dates, they are chronologically 18,300; 20,300; 21,600; 22,600; 25,000; and 29,000 years. This emphasis is made for two reasons: (1) These absolute dates fall within the period of loess deposition in the state of Iowa (table 4). Inescapably, the conclusion is mandatory that *the Iowan surface was being cut while loess was being deposited in the region.* (2) These absolute dates encompass the parts of the Wisconsin Pleistocene that include Farmdale through Tazewell, currently Farmdalian through part of the Woodfordian in Illinois (Frye and Willman, 1960, p. 1-2). These dates also are restricted to that part of the Iowan surface that is covered by loess. Presumably, the surface beneath the loess could be as young as 14,000 years, which dates the close of major loess deposition in Iowa (table 4).

The Iowan surface is also younger than the loess. At Alburnett paha the loessially buried and preserved summit is 20,700 ± 500 years (I-2332). This buried summit is a part of the Iowan surface whose radiocarbon age falls within the chronological span of 18,300 to 22,600 years for surfaces at Palermo, Salt Creek, and Geneseo. The lower level (fig. 10) that is loess-free but mantled by loam sediments is 12,700 ± 290 years (I-2333) and younger. This date is late Cary in age and equates with the Algona morainal phase of the Des Moines lobe (Ruhe and Scholtes, 1959, p. 592).

The Iowan surface, where covered by loam sediments, is also younger. One mile north of Sumner in Bremer County, the stone line surface crosses hill summits and slopes on which Kenyon, Ostrander, and associated soils are formed. The stone line passes beneath a shallow drainageway in which a peat bog has formed. The loam sediments grade laterally down hillslopes of 2 to 5 percent gradient to the bog sediments. At a depth of 88 to 91 inches at the base of the bog, the radiocarbon age is 11,880 ± 170 years (I-1862). At a depth of 54 to 57 inches the date is 6,130 ± 120 years (I-1861), and

Table 4. Radiocarbon Chronology of the Wisconsin Loess in Iowa

Sample[1]	Date[2]	Location	Notes
Top of loess (base of Cary)			
I-1402	14,200 ± 500	Nevada, Story County	Spruce wood
W-512	14,470 ± 400	Scranton, Greene County	Fir, hemlock, larch, spruce wood
W-153	14,700 ± 400	Clear Creek, Story County	Hemlock wood
Within loess			
I-1270	16,100 ± 1,000	Boone, Boone County	Spruce wood
I-1024	16,100 ± 500	Madrid, Polk County	Spruce wood
C-528	16,367 ± 1,000	Clear Creek, Story County	Hemlock wood
W-126	16,720 ± 500	Mitchellville, Polk County	Yew, spruce, hemlock wood
C-481	> 17,000		
W-1687	18,300 ± 500	Salt Creek, Tama County	OC, residue
I-1409	20,300 ± 400	Dysart, Tama County	OC, residue
Base of loess, southwestern Iowa traverse			
I-1023	21,360 ± 850	Bentley, Pottawattamie County	Spruce wood
I-1420	23,900 ± 1,100		OC, residue
W-141	24,500 ± 800	Hancock, Pottawattamie County	Larch wood
I-1411	18,700 ± 700	Greenfield, Adair County	OC, residue
I-1410	20,900 ± 1,000	Murray, Clarke County	OC, residue
I-1419A	16,500 ± 500	Humeston, Wayne County	OC, humic acid fraction
I-1419B	19,000 + 6,000 − 3,000		
I-1408	19,200 ± 900	Harvard, Wayne County	OC, residue
Base of loess			
W-879	19,050 ± 300	Logan, Harrison County	Spruce wood
I-1403	23,900 ± 1,100	Grinnell, Poweshiek County	Peat, conifer zone
I-1022	20,290 ± 1,000	Kinross, Keokuk County	OC
I-1406	24,600 ± 1,100		OC, residue
I-1267	25,000 ± 2,500	Dysart, Tama County	OC, residue
I-1269	29,000 ± 3,500	Salt Creek, Tama County	OC, residue

[1] C – University of Chicago, I – Isotopes, Inc., W – U. S. Geol. Survey, Washington.
[2] Years before present.

at a depth of 27 to 30 inches, the age is 2,930 ± 110 years (I-1860). Consequently, the adjoining Iowan surface is as young as 11,880 years, and parts of it are as young as 6,130 and 2,930 years. These dates are postglacial or Recent in the state of Iowa.

A preliminary scan of the pollen spectrum of the Sumner bog (fig. 11) shows the dominance of conifers and hardwoods until 6,130 years ago which, in turn, was followed by the dominance of grass. After 2,930 years resurgence of oak is indicated in the grassland regimen. This sequence and chronology fits the framework within the post-Cary bogs on the Des Moines lobe (Walker, 1966, p. 873). The earliest conifer zone is also substantiated in the 12,700 year horizon at Alburnett. The dated sample was spruce wood.

The extremely young age of the hillslopes of the Iowan surface is also documented in the Geneseo area. There the hillslopes descend to valley fills that join the third floodplain or terrace level above Wolf Creek. An American elm log buried 9 feet below the surface of the alluvial fill is 2,080 ± 115 years old (I-1421). This alluvium had been identified as "Iowan terrace gravel" (Kay and Miller, 1941, p. 146).

Thus, the Iowan surface is indeed a complex geomorphic feature. Components of it may range in absolute age from 30,000 years to the last few millennia. This is the surface that was previously simply explained as primarily a glacial depositional surface that was subsequently only somewhat slightly modified by slope wash and wind deflation. Obviously, these previous ideas must be dropped and the true nature of the Iowan surface must be recognized for what it is.

Loess

In previous studies on the Iowan and continuing very recently (Leighton, 1960, p. 541-542) great emphasis has been placed and rightly so on the thick loess around the Iowan border and the thinning of loess away from the border. The Iowan surface has been considered as a source of loess. However, the thick loess deposits of the paha and inliers well within the Iowan border and their fit within the regional loess picture have been neglected and avoided. These isolated areas have been treated as local problems. They are in part, but they also fit within the regional picture.

The Iowan border, in general, is paralleled by a 32-foot loess thickness isopleth (Thorp and Smith, 1952). The loess then thins away from this border area to 16, 8, or less feet. On the Iowan surface from the southern border and the Des Moines lobe border, the loess thins

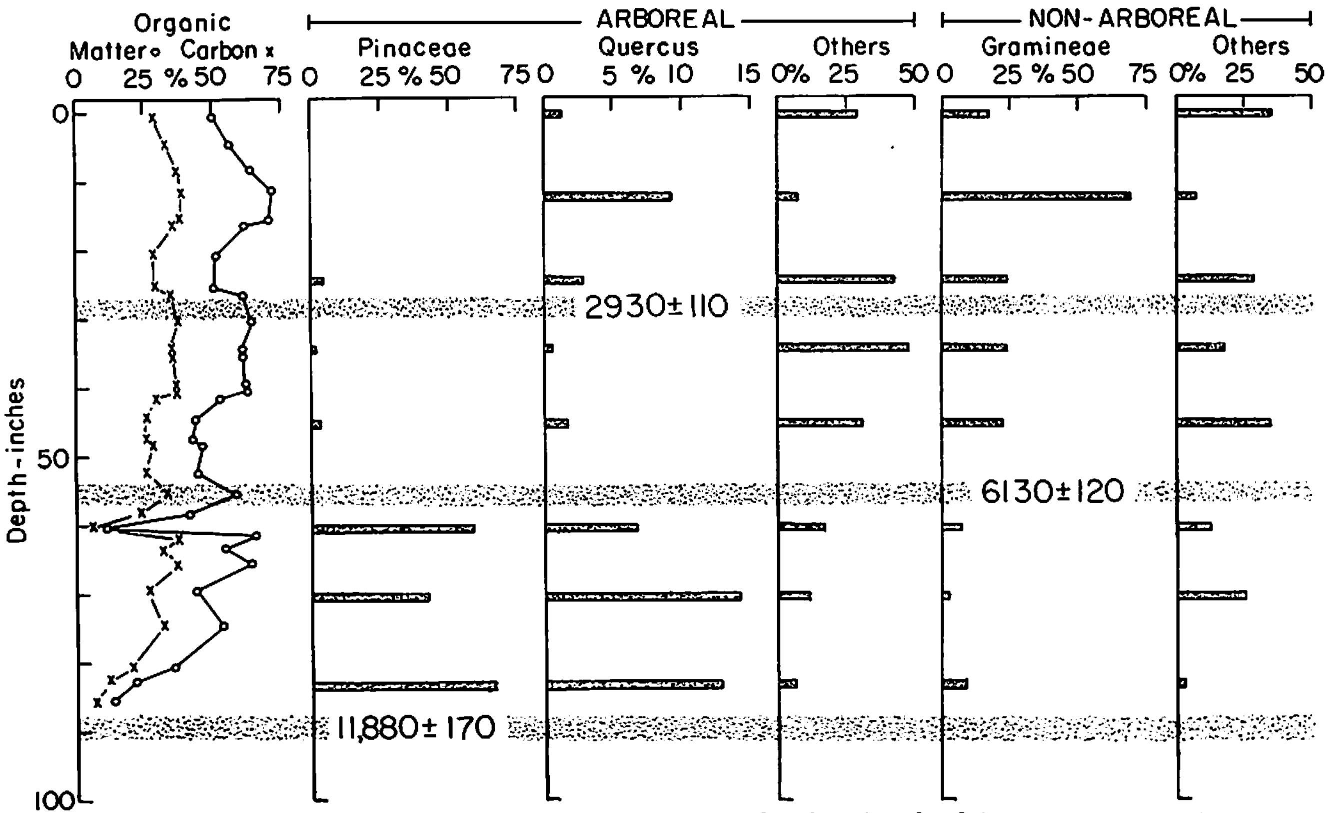

Figure 11. Organic stratigraphy, pollen spectrum scan, and radiocarbon dated horizons in Sumner bog.

across the Iowan northeasterly to the line from Cerro Gordo to Benton and Linn Counties where thin loam sediments are on the Iowan surface.

Within the Iowan area, 116 paha and inliers have been mapped (Scholtes, 1955) and are as far behind the border as Bremer, Butler, Floyd, and Franklin Counties (fig. 1). However, 80 percent of the paha are within a distance of 22 to 50 miles behind the border in Tama, Benton, Linn, Buchanan, Delaware, Jones, Cedar, and Clinton Counties.

The thickness of loess including the sandy zones on the paha is very similar to the thickness in the immediate border area. For example, at Hayward's paha the loess is 36 feet thick and at Fourmile Creek paha the loess is 34 feet thick. These locations are 15 to 20 miles behind the border. In the Salt Creek border area, thicknesses of loess on summits in the Kansan area are 28, 31, 32, and 44 feet. In the Alburnett paha the loess is 44 feet. Thus, there is a similarity in this property of the loess at and behind the border.

A second critical similarity in properties is the sedimentological zoning of the loess in the border area and in the paha. A basal zone of the loess on the paha is relatively sand-free. The intermediate zone contains considerable sand, and a upper zone is relatively sand-free. At Salt Creek the intermediate sandy zone, when traced from drill core to drill core across the border and downward onto the Iowan surface, descends from an interbedded position to the basal zone of the loess on the Iowan surface (fig. 8). The textural zoning is substantiated by laboratory analysis (table 3). In the paha and adjacent Iowan surface at Fourmile Creek, the same relationships hold true (fig. 6; table 2) and are also substantiated by laboratory data (table 2). A third very similar landscape and sedimentological system is at and adjacent to Hayward's paha in the Geneseo area (table 5; cf. fig. 9).

The basal relatively sand-free zone represents the loess increment that fell on the landscape during the early period of loess deposition in Iowa (table 4). This increment in part pre-dates and in part relates to the cutting of the Iowan erosion-surface complex. At Salt Creek this increment was deposited after 29,000 years ago and before 18,300 years ago (fig. 8). At Hayward's paha the basal increment was deposited after 25,000 years ago and before 20,300 years ago. Absolute values are not available for the Fourmile Creek area.

Table 5. Particle-Size Analysis and Stratigraphy of Cores at Hayward's Paha

PAHA — CORE NO. 2

Depth (ft.)	Particle size: Sand-% (>62μ)		Particle size: Silt-% (62-2μ)	Particle size: Clay-% (<2μ)	CaCO3 equiv. (%)	
0-0.58	1.5		71.2	27.3	0.0	
0.58-1.08	1.1		69.1	29.8		
1.08-1.33	1.2		68.0	30.8		
1.33-1.58	1.2		67.6	31.2		
1.58-1.92	1.7		67.3	31.0		
1.92-2.33	1.3		67.8	30.9		
2.33-2.83	1.3		68.9	29.8		
2.83-3.17	2.1		69.4	28.5		LL
3.17-3.50	1.5		70.6	27.9		
3.50-4.00	1.8		71.3	26.9		
4.00-4.50	4.6		69.8	25.6		
4.5-5.5	2.7		74.7	22.6		
5.5-6.0	14.0		69.2	16.8		
6.6-7.3	22.5		60.0	17.5		
7.3-8.0	25.6		58.2	16.2	0.0	
8.0-9.8	27.2	SZ	55.9	16.9	1.6	
9.8-11.0	12.6		73.2	14.2	9.8	
11.0-11.5	7.8		79.0	13.8	—	
15.0-15.5	6.3		80.5	13.2	11.8	
20.4-20.8	6.6		79.7	13.7	15.1	CL
25.0-25.5	4.4		81.2	14.4	14.9	
31.0-31.5	2.7		82.5	14.8	10.8	
33.5-34.0	1.0		87.4	11.6	6.9	
34.2-34.5	3.4		87.8	8.8	1.3	
36.4-36.9	0.7		57.5	41.8	1.4	
36.9-37.0	0.6		53.9	45.5	0.0	Pl

IOWAN SURFACE — CORE NO. 6

Depth (ft.)	Particle size: Sand-% (>62μ)		Particle size: Silt-% (62-2μ)	Particle size: Clay-% (<2μ)	
0.0-0.50	6.6		66.8	26.6	
0.50-1.08	4.0		65.8	30.2	
1.08-1.42	5.0		67.5	27.5	
1.42-2.00	5.1		67.8	27.1	
2.00-2.33	5.3		69.7	25.0	
2.33-2.58	2.8		73.2	24.0	LL
2.58-3.17	5.2		73.5	21.3	
3.17-3.67	5.8		72.6	21.6	
3.67-4.17	4.1		73.0	22.9	
4.17-5.00	4.1		73.6	22.3	
5.0-5.5	1.6		76.2	22.2	
5.5-6.1	2.4		78.5	19.1	
6.7-8.0	2.9		81.2	15.9	CL
8.0-12.9	6.3		76.0	17.7	
14.6-15.0	22.4	SZ	62.3	15.3	
16.8-17.0	39.0		48.8	12.2	CS
19.0-19.8	31.3		54.3	14.4	
20.8-22.0	36.7		37.9	25.4	LT

IOWAN SURFACE — CORE NO. 8

Depth (ft.)	Particle size: Sand-% (>62μ)		Particle size: Silt-% (62-2μ)	Particle size: Clay-% (<2μ)	
0-0.50	1.4		71.1	27.5	
0.50-0.83	0.9		69.0	30.1	
0.83-1.08	1.0		67.1	31.9	
1.08-1.42	1.2		66.6	32.2	
1.42-1.75	1.9		65.8	32.3	
1.75-2.08	1.8		66.9	31.3	
2.08-2.58	1.9		68.5	29.6	
2.58-3.08	1.5		71.2	27.3	LL
3.08-3.42	1.2		73.1	25.7	
3.42-3.83	2.9		71.6	25.5	
3.83-4.17	6.4		68.1	25.5	
4.17-4.58	2.1		73.3	24.6	
4.58-5.00	1.4		73.9	24.7	
5.0-5.5	4.7		71.8	23.5	
5.5-5.8	21.4	SZ	57.2	21.4	LS
6.0-6.8	44.6		31.3	24.1	
6.8-7.7	31.2		40.3	28.5	LT
7.7-8.1	34.2		38.8	27.0	

Symbols: SZ - sand zone; LL - leached loess; CL - calcareous loess; LS - leached sand; CS - calcareous sand; Pl - paleosol; LT - leached till.

The sandy zone represents the period of active cutting of the Iowan erosion-surface complex. The source of the sand is the sand in the loam till into which the erosion surface was cut. The vector of distribution of sand must be from this lower level source onto the higher level extra-border area or erosion remnant within the paha. The vector of distribution can not be the other way. There is no adequate source of sand in the basal loess increment on the higher landscapes. The agent of distribution of sand must have been wind. The sand was blown from the lower to the higher level. The agent making sand available on the lower level was running water. It lagged the gravel, the stone line, on the till and size-sorted particles for both water transport down gradient and wind transport to higher levels. These episodes culminated at Salt Creek 18,300 years ago and at 20,300 years ago at Geneseo.

The upper, relatively sand-free zone of the loess represents the latest increment of loess deposition in Iowa that culminated 14,000 years ago (table 4). This is the increment that blankets most levels of the landscape in the loess-mantled part of the region of the Iowan surface. One result of this incremental deposition is that locally different thicknesses of loess are on different levels of the landscape. The maximum thickness is on the remnantal divides. Loess thickness decreases down the stepped levels. As each lower level is successively younger, less time was available for incremental deposition. The local thickness distribution is peripheral to the remnantal divides.

Another result of the last increment of deposition has been the homogenization of the soil landscape so that soils are very similar in comparable local topographic environments regardless of the level of the landscape on which they occur. In these controlled topographic sites the constructional land surface dates from the time of completion of loess deposition about 14,000 years ago. For example, in the Geneseo area with its multi-leveled landscape, the Tama soil is on four topographic levels. The lowest level has 3.5 feet of loess overlying alluvial sands on a terrace that is 19 feet above Wolf Creek. A second level is 130 feet above stream level and has a loess mantle 5 to 7 feet thick. A third level at 155 feet above Wolf Creek has 7 to 10 feet of loess on it. The divide of Hayward's paha has 36 feet of loess. Properties of soils formed in the loess on the four levels have sets of similarities and sets of differences (fig. 12). Clay, organic carbon, and organic phosphorus distributions in the profiles are very similar with the slight exception of the soil on the terrace. Base saturation and cation exchange capacities show some divergence. Base saturation distributions show a displacement of lower to higher values from the terrace to the divide and to the erosion levels. The differences in leaching thus indicated are probably explained by the subsurface permeabilities of underlying sediments. The terrace is underlain by permeable sands that are 40 feet thick. The divide is underlain by readily permeable loess that is 36 feet thick. The soils in loess on the erosion surfaces, however, are underlain by relatively more impermeable till at depths of only 5 to 7 feet.

Current Study, Previous Evaluations, and Implications

The results of this current study agree with Leverett's evaluation prior to his conciliation in 1942 that the Iowan till does not exist. In this regard there is disagreement with the conclusions of McGee, Calvin, Alden and Leighton, Kay and associates, and Leighton. There is disagreement with Leverett that the till in northeastern Iowa is a late phase Illinoian. The till beneath the loess or loam sediments is either Kansan or Nebraskan.

The results of the current study agree with Leverett's evaluation that the stone line (Iowan pebble band) was formed mainly by erosion by running water, but there is disagreement that much time was involved in its formation. But involved herein is the quantification of how much is "much". In this latter regard there is agreement with Kay and associates and Leighton that the stone line and the loess are closely related in time. The current studies show that the Iowan erosion surface formed during loess deposition time.

There is agreement with Leverett that the loess is much younger than the drift. In the current study the loess is Wisconsin in age and the tills are Kansan and Nebraskan. Consequently, there is disagreement with Kay and associates and Leighton that the loess and stone line are closely related in time to the drift.

There is agreement with previous evaluation that the Iowan surface served as a loess source. Sand was added to the loess of divide remnants and to the Kansan area at the border. Certainly, silt also would have been available for eolian transport.

The results of the current studies have serious implications in other parts of Iowa. (1) A question may be raised concerning the validity of the Iowan drift of northwestern Iowa (Smith and Riecken, 1947; Ruhe, 1950, 1952). Prior to assignment of "Iowan" to this region, it had been considered Kansan with the "Kansan gumbotil" stripped by erosion (Kay, 1917, p. 218-219; Carman, 1917, p. 332-334; Kay and

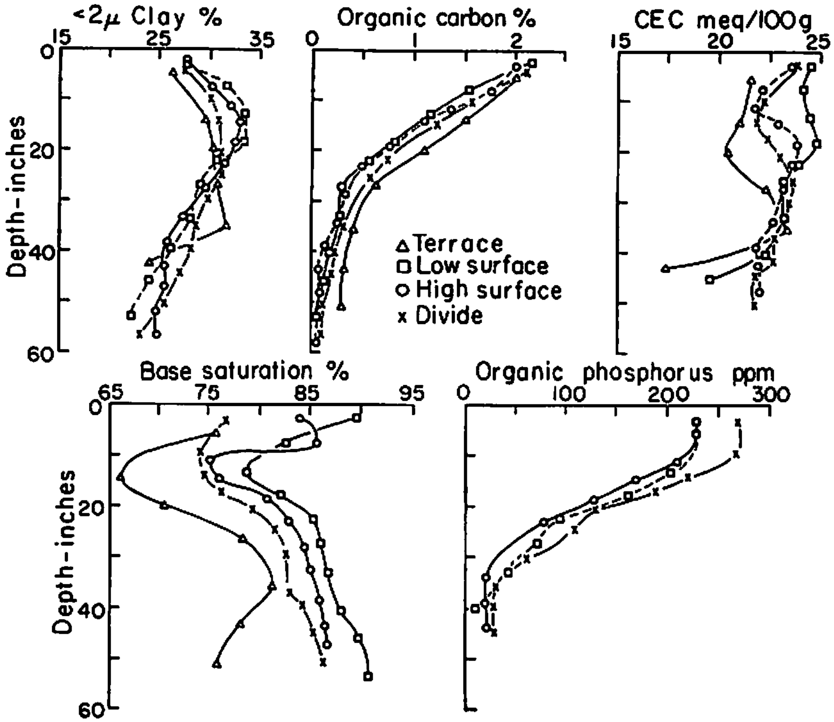

Figure 12. Soil-property data of Tama silt loam formed in Wisconsin loess. Each profile is a similar site on each of four landscape levels.

Apfel, 1929, p. 113-118, 216-217; Carman, 1931, p. 103-107). The current studies in the "type Iowan" region in northeastern Iowa indicate that earlier opinions of erosive stripping of Kansan till in northwestern Iowa are true in northeastern Iowa.

(2) The part of northwestern Iowa that was Carman's Iowan (1931, p. 39-102) was reclassified as Tazewell by Ruhe (1950, 1952), and this reclassification still holds. This drift body does exist and is substantiated by radiocarbon dates. Spruce wood from the base of this till at Cherokee, Iowa, is 20,000 ± 800 years old (O-1385). In the well-known Sheldon cut in O'Brien County, the Tazewell till overlies a buried soil whose A-horizon organic carbon is 20,500 ± 400 years old (I-1864A). To the eastward this till with overlying loess passes under the Cary till whose base is dated at 14,000 years (table 4). This span between 14,000 to 20,500 years fits neatly in the Tazewell of Illinois (Frye and Willman, 1960, p. 2-3).

However, the Iowan erosion surface, defined in the current studies, crosses the Tazewell drift of northwestern Iowa. The drainage net on the Kansan drift (circa 1947-1952) extended headward and integrated on the Iowan drift (circa 1947-1952). The drainage net further extended headward and integrated on the Tazewell drift. Drainage-net maps show this (Ruhe, 1952, p. 51). Drainage-density values for these three surfaces in order are 10.2 and 7.9; 7.7 and 6.1; and 5.4 and 4.7 respectively. The drainage net has not extended headward and integrated on the Cary drift surface, and its drainage density values are 2.1 and 1.9. Each of these samples of density determination is 144 square miles. Consequently, the drainage net on the Tazewell surface of northwestern Iowa had to extend headward and across the Tazewell between 20,000 and 14,000 years ago. This time span also fits within the chronology for the Iowan erosion surface in northeastern Iowa.

(3) A third problem arises in the physiographic history of extinct Lake Calvin which is only 25 miles south of the Alburnett area and which is an embayed area in the Iowa and Cedar River valleys. As recently reviewed (Ruhe, 1965, p. 114-115), Lake Calvin can not be related to Illinoian glaciation as previously believed and for the following reasons:

(A) The Late Sangamon erosion surface (Ruhe, 1956, p. 450-452) that is a common feature beneath the Wisconsin loess in the southern half of Iowa, crops out on slopes as much as 80 feet above the highest terrace of Lake Calvin. The Late Sangamon paleosol is in road cuts along U. S. Highway 218 about 2 miles north of the State Highway 22 intersection. The lower Lake Calvin terraces have to be younger than the Late Sangamon surface as they are inset below it. They can not be Illinoian.

(B) In reconnaissance coring on the terraces, at no place is a paleosol present at the top of the alluvial sediments of the terraces where capped by Wisconsin loess. If the alluvium is Illinoian, then a Sangamon paleosol should intervene just as it does between Illinoian glacial till and Wisconsin loess and Loveland and Wisconsin loess at other places in Iowa. The flat, buried alluvial terrace surfaces preclude any extensive erosion prior to their burial by Wisconsin loess. The alluvium must be more closely related in time to the overlying loess which is Wisconsin in age.

(C) In the lower Iowa River valley below Lake Calvin, problems in terrace correlation between the lower valley and Lake Calvin led to the suggestion that the high terrace of Lake Calvin was not

Illinoian but Tazewell in age (Shaffer, 1954, p. 454-455). Our work confirms that of Shaffer, and is substantiated by radiocarbon dating. His "Sangamon peat" that is buried by the high terrace alluvium is 23,750 ± 600 (I-1865) and 23,050 ± 820 (OWU-167) years old. The high terrace alluvium must be younger and fits within Tazewell time.

(D) Erosional debris from the Iowan erosion surface formed in the Iowa and Cedar River basins above Lake Calvin had to be transported downstream into Lake Calvin and beyond. The radiocarbon dates *below* Lake Calvin fit within the chronological framework of the Iowan erosion surface *above* Lake Calvin. All of these features must be part and parcel of the same geomorphic system.

The implications of the current studies, then, require a re-examination of an appreciable part of the Pleistocene in Iowa.

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