# QUATERNARY GEOLOGY OF CONKLIN QUARRY

## GUIDEBOOK SERIES NO. 13

Iowa Department of Natural Resources
Larry J. Wilson, Director
April 1992

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prepared by

Timothy J. Kemmis, E. Arthur Bettis III,
and George R. Hallberg

Energy and Geological Resources Division
Geological Survey Bureau

April 1992

Prepared for North-Central Section, Geological Society of America
26th Annual Meeting, April 30-May 1, 1992, Iowa City, Iowa
Field Trip No. 3, April 30, 1992

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# PREFACE

Conklin Quarry has been studied by George Hallberg and a succession of colleagues since the early 1970's. These investigations detailed the complex stratigraphic succession at the quarry. This guidebook builds on a previous report by Hallberg et al. (1984). It includes some data from previous studies, but is rewritten to put more emphasis on secondary pedogenic and weathering changes to the units. It also updates till fabric and secondary joint data and revises lithostratigraphic and pedostratigraphic nomenclature for selected units. Additional data are presented in Hallberg et al. (1984), particularly for sections studied prior to 1983. We also wish to acknowledge the framework established in previous studies conducted in cooperation with Nyle Wollenhaupt, Steve Esling, and Tom Bicki.

For this guidebook, we have also summarized important paleoenvironmental interpretations made of the Angerer (Baker et al., 1984) and Conklin Quarry (Baker et al., 1986) Local Biota. We urge readers to consult these publications for important details of the research. These reconstructions provide important information about how paleoenvironments differed during the Quaternary.

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# INTRODUCTION

The pre-Illinoian Quaternary sequence tends to be more difficult to interpret than Illinoian and Wisconsinan records. Not only is there a wide variety of facies, but facies interpretations are hindered by the deep weathering and pedogenic alteration which often pervade the stratigraphic sequence. Further, the sequence is replete with unconformities from multiple periods of glacial and subaerial erosion. The resulting record is greatly fragmented and stratigraphic units are rarely preserved as continuous sheets. Episodic erosion since the end of pre-Illinoian glaciation has resulted in development of an integrated drainage network across virtually the entire area that has destroyed any pre-Illinoian glacial landforms. Conklin Quarry exemplifies these various complications and is: 1) the most complete *exposure* of pre-Illinoian glacial deposits known; 2) one of the few sites in which paleomagnetic studies have been made of glacial tills; and 3) one of the first sites from which faunal and floral evidence demonstrated tundra-like environments during the Wisconsinan maximum in the upper Midwest. The sequence at Conklin Quarry is also of interest because new exposures made over the past 15 years have revealed much about the nature of pre-Illinoian stratigraphic sequences. For this trip, we will walk through the stratigraphy, noting the secondary weathering and erosional features that make investigation of pre-Illinoian Quaternary sequences a challenge requiring knowledge not only of stratigraphy and sedimentology, but of pedogenesis and geomorphic (hillslope) processes as well.

### Methods and Jargon

Stratigraphic sections at Conklin Quarry have been described at various times since 1975 as new sections have been exposed. Lithofacies are designated using a lithofacies code modified from Miall (1977) and Eyles et al. (1983) (see sidebar p. 2). Standard pedologic terminology and horizon nomenclature (Soil Survey Staff, 1951, 1975; Guthrie and Witty, 1982) have been used in describing the soils and paleosols. For convenience, enumeration of different parent materials within a paleosolum begins with the uppermost material in the paleosol rather than at the present landsurface. Standard weathering zone terminology (Hallberg et al., 1978a; see sidebar p. 3) is used for sediments below the solum or paleosolum. Textures are described using U.S.D.A.-S.C.S. textural classes and terminology (Soil Survey Staff, 1975; Walter et al., 1978). Laboratory data are presented to quantify the physical properties of the materials. Laboratory methods include: particle-size analysis (Walter et al., 1978), clay mineralogy (Hallberg et al., 1978b), sand-fraction mineralogy (Lucas et al., 1978), and matrix carbonate content using the Chittick apparatus (Walter and Hallberg, 1980). Fabric analysis of the diamictons was based on the measurement of the long-axis azimuth and plunge of prolate (rod-shaped) pebbles with a:b axial ratios of at least 2:1. For each analysis, twenty-five measurements were plotted on a lower hemisphere equal-area net and densities of points were contoured at two standard deviations using the method of Kamb (1959). Strengths of pebble orientations were evaluated statistically using the eigenvector method (Mark, 1973).

Abbreviations used on tables and figures include (modified from Hallberg et al., 1984):

| | |
|---|---|
| LS | -Late Sangamon |
| LSP | -("late") Sangamon Soil |
| LSPT | -("late") Sangamon Soil,truncated |
| LSES | -Late Sangamon erosion surface |
| LSPs | -Late Sangamon pedisediment/colluvium |
| IES | -Wisconsinan age Iowan erosion surface |
| BLS | -Pisgah Formation: loess, mixed loess and colluvium |
| BLP | -Farmdale Soil |
| IAC | -intra-Aurora Till Member contact |

## AN ABBREVIATED DESCRIPTION: THE LITHOFACIES CODE

Lithofacies codes are a convenient way to summarize deposit types and sedimentary structures. The code used here is modified from Miall (1977) and Eyles et al. (1983) and expanded to include codes for loess and colluvial deposits.

| CODE | LITHOFACIES |
|---|---|
| G__ | Gravel. |
| S__ | Sand, generally medium to coarse with minor gravel component. |
| Gm_ | Matrix-supported gravel. |
| Gc_ | Clast-supported gravel. |
| __p | with planar crossbeds. |
| __s | with cut-and-fill or scour structures. |
| __r | with ripple lamination. |
| | |
| F__ | "Fines;" silt and clay, matrix-dominated deposits. |
| _l_ | laminated; may include thin interbedded sands, small ripples |
| _m_ | massive. |
| _sc | laminated or thin-bedded silts and clays. |
| | |
| C__ | Poorly sorted colluvium, slopewash. |
| FC | fine-textured colluvium and poorly sorted overbank deposits. |
| | |
| L__ | Loess. |
| Lm_ | Loess, massive. |
| Ls_ | Loess, crudely stratified with slopewash. |
| Lse | Loess, interbedded with eolian sand. |
| | |
| D__ | Diamicton; poorly sorted deposits. |
| Dm_ | matrix-supported; clasts supported in <2 mm sand-silt-clay fraction; most diamictons in Iowa have <10% clasts. |
| Dc_ | clast supported. |
| D_s | stratified, with obvious textural differentiation between beds; often consists of thin beds of Dmm and sands (S) or silts (Fm). |
| D_(s) | sheared; includes structures indicative of shearing including overturned folds, low-angle thrusts between Dmm and substrate or block inclusions, smears, and smudges (incorporations of substrate materials which are sheared into thin, yet recognizable masses within the diamicton matrix); generally in subglacial facies. |
| __p | soil or paleosol developed in unit; pedogenesis has obscured most or all sedimentary features. |

## SOME NOTES ON WEATHERING ZONES

Standard abbreviations and symbols are used to describe weathering zones below the soil solum (O, A, E, and B horizons). These are defined by Munsell color (related to the state and distribution of free-iron oxides and organic matter) and the presence or absence of matrix-carbonate minerals (see Hallberg et al., 1978a for a complete discussion). In brief:

First symbol: color reference

| | |
|---|---|
| O | oxidized |
| D | deoxidized |
| R | reduced |
| U | unoxidized |

Second symbol: leached or unleached state

| | |
|---|---|
| U | unleached |
| L | leached; no carbonates detectable (with dilute HCl) |
| L2 | leached; primary carbonates absent, secondary carbonates present |
| U2 | matrix carbonates unleached, secondary carbonates present |

Modifier symbols:

M — mottled; zones containing 20-50% contrasting mottles; when used with unoxidized zone designation it infers 20% or less mottles of reduced colors; precedes first symbol when used.

J — jointed; describes the presence of well defined vertical joints; joints often show oxidized and reduced colors and often have coatings or rinds of secondary iron-oxides and occasionally other secondary minerals such as calcite or gypsum; second symbol when used.

Examples of descriptions using weathering zone terminology:

OL — oxidized, leached; yellowish-brown (10YR 5/6) or strong brown matrix color; leached.

MDU — mottled, deoxidized, and unleached; grayish brown (2.5Y 5/2) matrix color with strong brown (7.5YR 5/8) mottles and pipestems, unleached.

RJU — reduced, jointed, and unleached; mixed olive (5Y 4/4 and 5Y 4/3) and very dark grayish brown (2.5Y 3/2) matrix color with common gray (5Y 5/1) and light olive brown (2.5Y 5/4) mottles; prominent vertical joints with 1-cm thick strong brown (7.5YR 5/8) segregations along joints; unleached.

UJU — unoxidized, jointed, unleached; uniform dark greenish gray (5GY 4/1) matrix color with few thin vertical joints which have mottled light olive brown (2.5Y 5/6) and olive gray (5Y 5/2) faces and a 3-cm thick rind of greenish gray (5GY 5/1); unleached.

## THE QUATERNARY STRATIGRAPHIC SUCCESSION

The pre-Illinoian glacial deposits of Iowa are monotonously similar: where unweathered, the diamictons are all gray and have similar loam textures. As a consequence, it has been necessary to make stratigraphic differentiation using laboratory data rather than field properties. Further, the stratigraphic units are differentially preserved beneath different geomorphic surfaces that have developed as the drainage system evolved. A definitive stratigraphic sequence was constructed only after an exhaustive regional drilling program that included transects across the different surfaces and across bedrock valleys where the thickest and often most complete stratigraphic sequences were preserved (Hallberg, 1980a, b).

Pre-Illinoian deposits have been lithostratigraphically classified into the Alburnett Formation and younger Wolf Creek Formation (Hallberg, 1980a). Both formations consist predominantly of glacial diamictons (largely basal tills), but include other deposits as well. The formations and their members are differentiated by various physical and mineralogical characteristics (Hallberg, 1980a, b), but clay mineralogy (Table 1) is the main property used to distinguish between deposits at the formation level. Whereas some lithostratigraphic units, such as the Wedron and Glasford formations, also correspond to chronostratigraphic intervals, the Wolf Creek and Alburnett formations do not; each formation consists of multiple depositional units and paleosols, and includes deposits of several glacial and interglacial episodes. The Wolf Creek and Alburnett formations, therefore, are not correlative in any way to the former concepts of 'Kansan' and 'Nebraskan' glaciations, erroneous concepts based on inadequate stratigraphic data (e.g., Hallberg, 1986; Boellstorff, 1978). However, because of the fragmentary record for the pre-Illinoian, formal chronostratigraphic classification has not yet been developed. In western Iowa, where thicker sequences are preserved, stratigraphic units correlative to the Wolf Creek and Alburnett formations overlie still older glacial deposits (Fig. 1; Hallberg, 1986). In the absence of radiocarbon dating, absolute ages for the different stages are unknown, although fission-track ages on volcanic ashes buried within the western Iowa sequence provide some time control (e.g., Boellstorff, 1978; Hallberg, 1986). The oldest pre-Illinoian glacial deposit underlies a volcanic ash with a fission-track age of 2.2 million years B.P. ("B" on Fig. 1), and the youngest pre-Illinoian glacial deposit overlies a volcanic ash dated at about 610,000 years B.P. ("O" on Fig. 1), and is estimated to be about 500,000 years old (Hallberg, 1986). Paleomagnetic study of the detrital remnant magnetism (DRM) of sediments at Conklin Quarry indicates that deposits of the Alburnett Formation have reversed polarity, and are thus interpreted to be older than 790,000 years ago (the Bruhnes reversed/Matuyama normal boundary; Johnson, 1982), whereas deposits of the Wolf Creek Formation have normal polarity, and are younger than 790,000 years old (Baker, 1985; Baker and Stewart,

**Table 1.** Summary of clay-mineralogy data for the Wolf Creek and Alburnett formations of eastern Iowa (adapted from Hallberg et al., 1984).

| | Clay Mineralogy - %[1] | | |
|---|---|---|---|
| | Ex. mean ± s.d. | Ill. mean ± s.d. | K + C mean ± s.d. |
| | WOLF CREEK FORMATION | | |
| N = 476 | 61 ± 4 | 18 ± 3 | 22 ± 3 |
| | ALBURNETT FORMATION | | |
| N = 207 | 43 ± 6 | 25 ± 4 | 32 ± 4 |

[1]Ex. — expandable clays (smectite group); Ill. — illite; K + C — kaolinite and chlorite

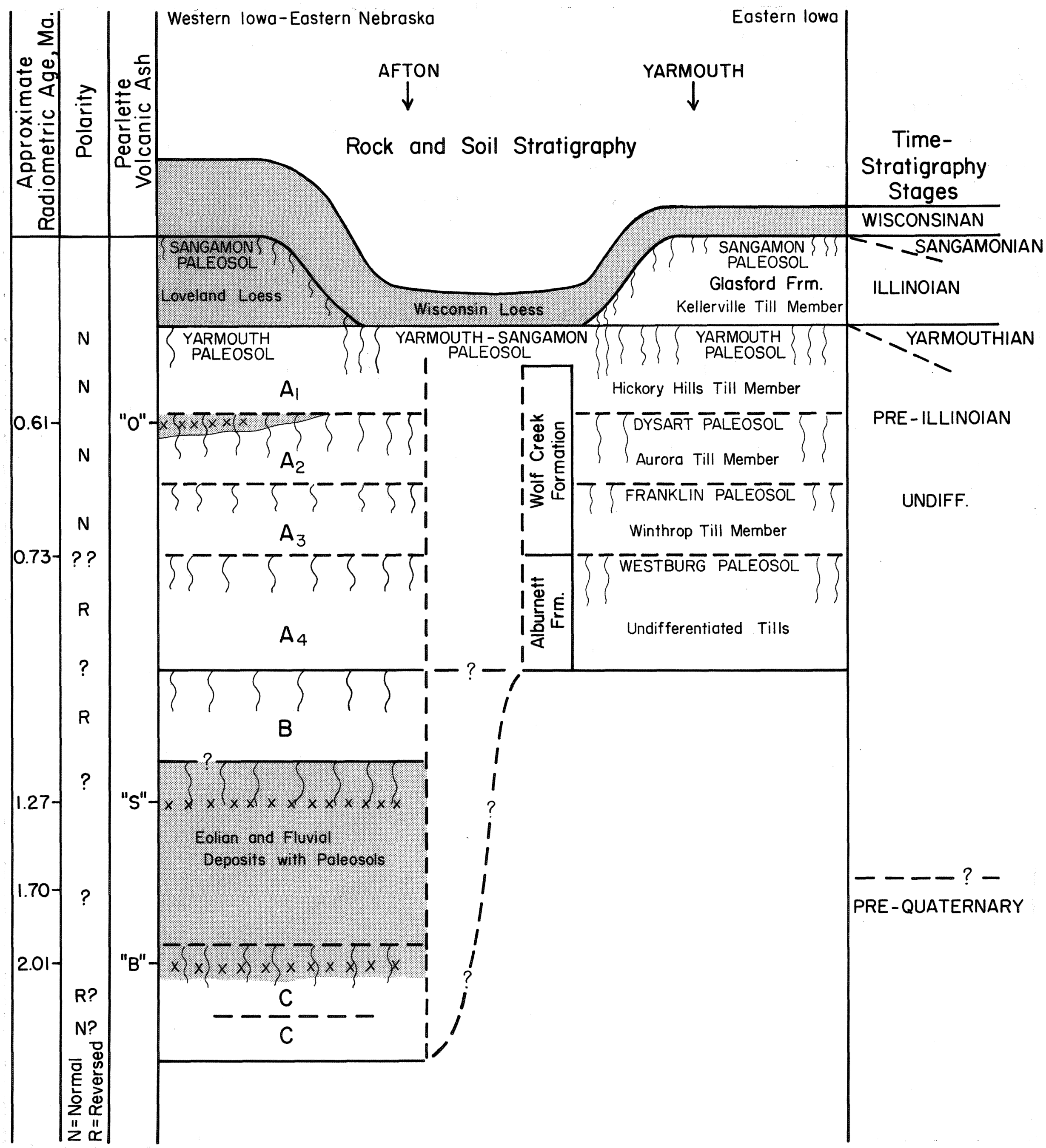



**Figure 1.** Current correlations between eastern and western Iowa Quaternary deposits showing approximate radiometric age, magnetic polarity, and position of volcanic ashes in the stratigraphic sequence.

1984).

The Wolf Creek Formation is dominated by massive, texturally and compositionally uniform basal tills, and is subdivided into members based on lithologic differences between these tills. Diamicton units within the Alburnett Formation, however, have virtually identical properties; as yet there is no way to differentiate or correlate Alburnett Formation deposits on a regional scale.

During the Wisconsinan two loess sheets were deposited across eastern Iowa. The oldest is a thin sheet that has largely been reworked by colluvial (and periglacial?) processes and pedogenically altered. This unit is referred to as the Pisgah Formation. Its stratigraphic position is the same as the Roxana Silt of Illinois and the Gilman Canyon Formation of Nebraska, but its lithologic properties differ. The youngest Wisconsinan loess is the Peoria Loess. These loesses mantle Wisconsinan and older geomorphic surfaces.

The Quaternary succession exposed at Conklin Quarry has varied through time with quarry operations (Figs. 2 and 3), and has provided an evolving picture of stratigraphic and geomorphic relationships at the site. The most complete stratigraphic successions were exposed in 1975-76 and 1983-84 (Fig. 2). To give a background on these previous, more complete sections, a description of the 1983-84 site is given in Table 2, stratigraphy and particle-size data are shown on Figure 4, and laboratory data are given on Table 3. The north end of the present site is approximately 150 m south of the 1983-84 site. Additional descriptions and data for exposures intermittently available from 1974 to 1980 are given in Hallberg et al. (1984).

## Alburnett Formation

The Alburnett Formation has distinctive clay-mineral composition that allows it to be distinguished from the Wolf Creek Formation (Table 1). At Conklin Quarry, Alburnett Formation deposits have somewhat lower smectite (expandable clay) (37%) and higher kaolinite (37%) than regional averages (Tables 1 and 4). Multiple diamicton units ("tills") are found regionally in the Alburnett Formation, but no consistent means of correlating these units have been found and no members have been formally defined. At Conklin Quarry, the Alburnett Formation has been comprised of as many as four units: two diamicton units and two fluvial units (Fig. 2). One fluvial unit occurs stratigraphically at the top of the formation and the other separates the two diamictons. Both diamicton units have been composed predominantly of massive, matrix-dominated diamicton, but have had lower zones of fissile diamicton containing inclusions of underlying substrate (clastic bedrock or sediment) that is often sheared and deformed. The entire Alburnett sequence will be described even though the lowermost fluvial unit and the underlying diamicton are absent from the present exposure (Fig. 3) because of glacial erosion associated with the uppermost diamicton.

### *Lowermost Diamicton*

***Facies.*** The lowermost diamicton is a complex unit only 1 to 2 m thick that is preserved in lows on the bedrock surface (Fig. 2). Bedrock striations associated with this unit trend ESE-WNW (106°-286°). The present exposure is on a bedrock rise, and this unit is absent. Structures throughout the diamicton unit have indicated formation in a subglacial environment, with evidence for deformation, lodgement, and melt-out. Facies have varied with the type of underlying bedrock. Where the diamicton overlay carbonates of the Devonian Cedar Valley Formation, it tended to be massive (facies Dmm; Fig. 2), but sometimes had pronounced horizontal fissility or platy structure [facies Dmm(s)] which likely resulted from subglacial shear and compaction. In places, the diamicton was interbedded with thin silt and sand stringers. The boundaries and geometry of these stringers varied. Some stringers were deformed into smudges (Krueger, 1979), suggesting subglacial deformation; others were undeformed and appeared to be small-scale glaciofluvial deposits formed in association with melt-out till (see Shaw, 1982). Where the diamicton overlay Pennsylvanian mudstones, shales, and sandstone, it was composed of two distinct increments. The lowermost increment [facies Dmm(s) and Dms] was thin (0.3 to 0.5 m) and dominated by sheared and deformed Pennsylvanian bedrock; smears, smudges, and block inclusions were common. This increment resembled deformation till described by Elson (1989). It graded upward to typical massive, matrix-dominated diamicton (facies Dmm).

***Mineralogy.*** The clay mineralogy of the diamicton varied with the facies. The lowermost sheared and deformed diamicton overlying Pennsylvanian bedrock [facies Dmm(s) and Dms] was composed of only illite, chlorite, and kaolinite, like that of the unaltered Pennsylvanian bedrock (Table 3). There was no smectite, and except for an occasional igneous cobble or pebble, there was little erratic debris. This increment graded upward to the overlying massive increment having

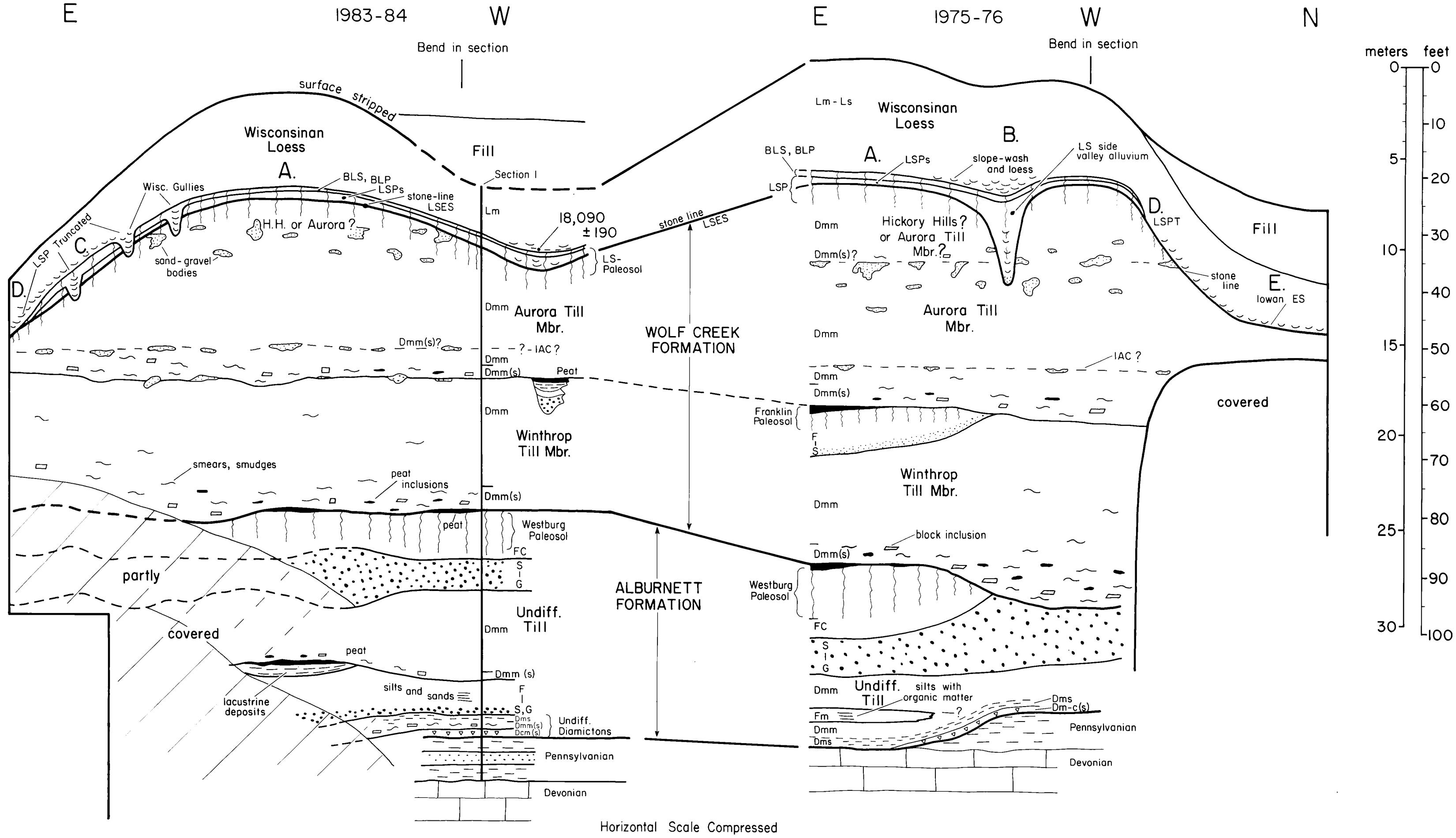



**Figure 2.** Schematic overview of the Quaternary stratigraphy and sedimentologic features at Conklin Quarry in 1975-76 and 1983-84.

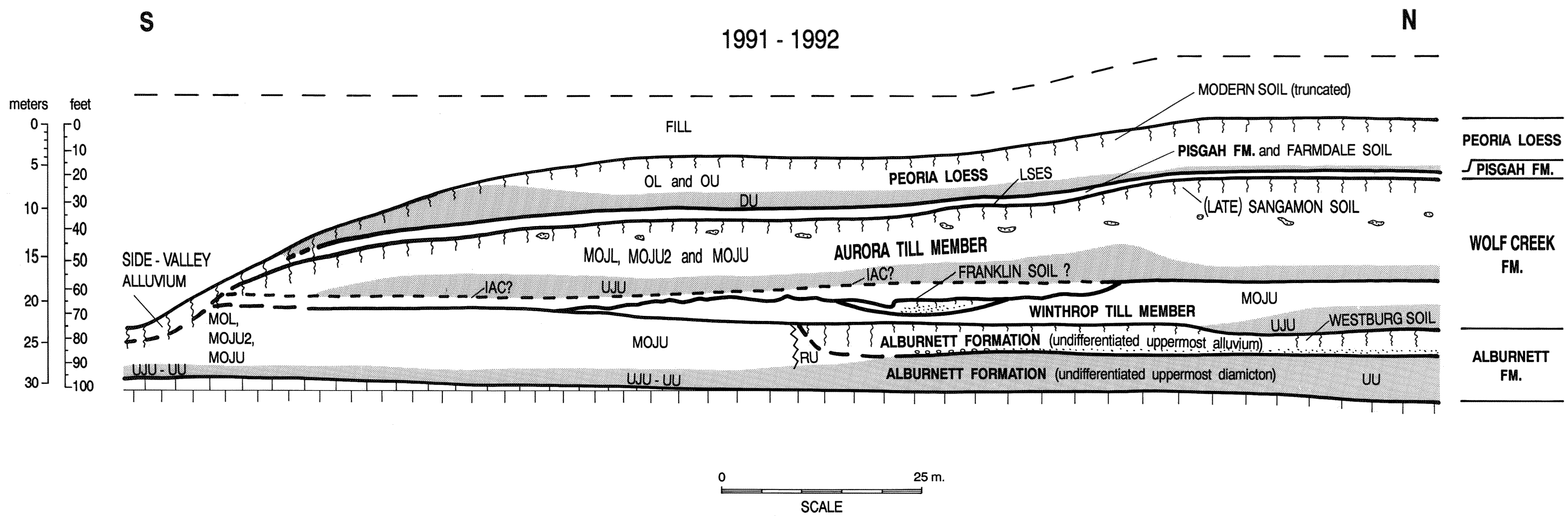



**Figure 3.** Stratigraphy and weathering zones of Quaternary deposits at Conklin Quarry in 1991-92.

**Table 2.** Abbreviated description for Section 1 of the 1983-84 exposure at Conklin Quarry (Section 1 is shown on Fig. 2; adapted from Hallberg et al., 1984).

| Depth feet (meters) | Horizon or Zone | Description |
|---|---|---|
| | PEORIA LOESS | |
| 0 - 5.1 (0 - 1.6) | | Fill; truncated soil and OL loess, silt loam. |
| 5.1 - 8.6 (1.6 - 2.6) | DU | Loess, silt loam, with snail shells (Lm). |
| 8.6 - 9.5 (2.6 - 2.9) | DL | Loess, silt loam, weakly calcareous locally (Lm). |
| | PISGAH FORMATION (BLS)<br>Farmdale Soil (BLP) | |
| 9.5 - 9.8 (2.9 - 2.98) | Ab | 10YR3/2, dark grayish brown; heavy silt loam; charcoal flecks (CP). |
| | WOLF CREEK FORMATION<br>Late Sangamon sediment (LSPs)<br>Sangamon Soil (LSP) | |
| 9.8 - 10.6 (2.98 - 3.23) | A/Eb | Silty clay loam to loam; platy; charcoal flecks (CP). |
| 10.6 - 11.6 (3.23 - 3.54) | Bt1b | Strong brown to reddish brown; heavy clay loam (CP). |
| 11.6 - 12.1 (3.54 - 3.69) | Bt2b | Strong brown to reddish brown; clay; stone line at base (CP). |
| | Aurora Till Member<br>Sangamon Soil (continued) | |
| 12.1 - 14.1 (3.69 - 4.30) | Bt3b | Reddish brown; clay to heavy clay loam till (DmmP). |
| 14.1 - 16.1 (4.30 - 4.90) | Bt4b | Strong brown to reddish brown; heavy clay loam till (DmmP). |
| 16.1 - 17.1 (4.90 - 5.21) | C-MOJL | Heavy loam till (Dmm). |
| 17.1 - 17.6 (5.21 - 5.36) | MO-RJL2 | Loam till, with large carbonate concretions (Dmm). |
| 17.6 - 19.6 (5.36 - 6.0) | MO-RJU2 | Loam till (Dmm); with large carbonate concretions in matrix and joints; numerous deformed sand and gravel (S,G) inclusions from 12 to 19.6 feet laterally from this section; in places till seems deformed (Dmm(s)) around s & g bodies. Locally paleosol developed in sand and gravel. Laterally, to east (100 feet) on exposure the Late -Sangamon surface rises in elevation and there is about 8 feet of (light loam) till above sand-and-gravel zone. This zone may mark break between Hickory Hills and Aurora till members or may be intra-Aurora subdivision (below or within 19-22 foot zone). |
| 19.6 - 21.6 (6.0 - 6.6) | MO-RJU2 | Till (Dmm), as above, but few sand lenses. |
| 21.6 - 28.1 (6.6 - 8.6) | MRJU | Loam till (Dmm). |
| 28.1 - 33.8 (8.6 - 10.3) | MUJU | Loam till (Dmm). |

**Table 2.** (continued)

NOTE: 28.1 - 33.8 ft. horizon, MUJU loam till, Aurora Till Member; in this horizon occurs a discontinuous zone of water seepage and thin (0.1 - 1.0 ft) discontinuous sand-and-gravel lenses; till (Dmm(s)) shows pronounced fissile parting around some of these lenses, and in zones between lenses, providing discontinuity for seepage; some minor oxidation (MRJU) occurs around sand lenses. This zone is continuous for over 250 feet laterally; likely till-till contact within Aurora Till Member (IAC on Fig. 2: Intra-Aurora Contact).

| | | |
|---|---|---|
| 33.8 - 36.3 (10.3 - 11.1) | UJU | Loam till (Dmm(s)); 5Y3/2 and 5GY4/1. Lower 2-5 feet with block inclusions, sheared inclusions, smudges of underlying till, peat, sand and silt lenses. A few deformed sand lenses at lower contact may be related to this till. Contact varies laterally from abrupt till-till contact, to till over sand or silt inclusions. Lower boundary described at abrupt till-till contact. Some joints continue from one till to next. |
| | Winthrop Till Member | |
| 36.3 - 40.3 (11.1 - 12.3) | MR-MOJU | Heavy loam till (Dmm); mixed 2.5Y4/2, 2.5Y4/1, 10YR 5/4; 10YR and 7.5YR4/6, 5/4, 5/6-8 mottles and joint coatings. Locally, preserved swales on the Winthrop surface show Aurora till over 3 feet of peaty silt (Oeb), over 1 foot of mucky silt loam (Ab), over 2 to 3 feet of RL to RU sandy loam (S) and thinly bedded silt loam (F) inset in steep-sided swale or gully (?) in MRU Winthrop Till. This is a "facies" of the Franklin Soil; a weakly developed O-A-C profile. |
| 40.3 - 42.8 (12.3 - 13.0) | MRJU | Loam till (Dmm). |
| 42.8 - 56.8 (13.0 - 17.3) | MR-MUJU | Loam till (Dmm). |
| 56.8 - 58.2 (17.3 - 17.7) | MR-MUJU | Heavy loam till (Dmm(s)); with sheared inclusions and smudges of underlying paleosol (Ab) and wood; abundant smudges of Pennsylvanian mudstone; some MOJU around inclusions; abrupt lower boundary where described. |
| | ALBURNETT FORMATION<br>Uppermost fluvial unit<br>Westburg Soil | |
| 58.2 - 59. 7 (17.7 - 18.2) | Ab and A/Bb | 5Y2/1 - N2/0; mucky silty clay loam to clay loam (FCP); compressed; in some areas soil structure deformed into massive sheared blocks; locally wood and thin (0.5 feet) fibrous peat at upper contact. Wood previously identified as spruce. |
| 59.7 - 62.2 (18.2 - 19.0) | Btg1b | Silty clay (FCP); mottled 5Y3-4/1, 5GY4/1. |
| 62.2 - 64.4 (19.0 - 19.6) | Btg2b | As above, heavy silty clay loam to clay loam (FCP). |
| 64.4 - 65.8 (19.6 - 20.1) | Btg3b | As above, clay loam (FCP); abrupt lower contact. |
| 65.8 - 66.9 (20.1 - 20.4) | Btb (Beta B?)- MRL | 2.5Y5/3, sandy clay loam sediment (FC-SP). |
| 66. 9 - 72.5 (20.4 - 22.1) | OL | Stratified sand, sandy loam, with some fine gravel; abrupt lower contact; coarse, clast-supported gravel at till contact (Sp grading to GcP). |
| | Uppermost diamicton unit | |
| 72.5 - 73.0 (22.1 - 22.3) | UL | Loam till (Dmm). |
| 73.0 - 76.0 (22.3 - 23.2) | UU | Loam till (Dmm). |
| 76.0 - 84.5 (23.2 - 25.8) | UU- UJU | Loam till (Dmm). |
| 84.5 - 87.7 (25.8 - 26.7) | MUJU-MRJU | Very dense, hard loam till (Dmm). |
| 87.7 - 88.5 (26.7 - 26.9) | MRJU | Till (Dmm(s)); fissile, medium to thick platy, with Fe-oxide stains on plates; abrupt lower contact with stratified deposits; few inclusions of sand from below. |

**Table 2.** (continued)

| | | |
|---|---|---|
| | Lowermost fluvial unit | |
| 88.5 - 90.0 (26.9 - 27.4) | MUU-UU and MR-MOU | Interbedded silts (MUU-UU), and sands (MR-MOU); deformed to below till contact 2.5 feet, common soft-sediment deformation structures; some shear structures with thrusts, overturned folds; generally overturned from north to south. |
| 90.0 - 93.3 (27.4 - 28.4) | UU-MUU | Thinly bedded to laminated silts and silt loam; some organic-rich beds. |
| 93.3 - 93.7 (28.4 - 28.6) | OU | Sand, medium grained, massive. |
| 93.7 - 94.0 (28.6 - 28.7) | MRU | Diamicton, with thin sand and silt stringers. |
| 94.0 - 94.3 (28.7 - 28.8) | MOU | Sand, medium grained, massive. |
| 94.3 - 94.5 (28.8 - 28.8) | OU | Iron-oxide cemented sandy loam with gravel, 5YR6/4; Gms; lag on diamicton below; gravel is matrix supported; matrix sometimes silt loam; pebbles angular. |

NOTE: Laterally (to east) the interbedded silts and sands grade into (? or are angularly truncated by) more sand-dominated facies; 0.8 - 1.5 foot thick beds of medium sand, with climbing ripples. To the east, the overlying till rises in elevation (2-3 feet) and more of the water-laid section is preserved. About 200 feet east of measured section, S. Rhodes section shows:

| | | |
|---|---|---|
| | Uppermost diamicton unit | |
| 0 -2.0 (0 - 0.61) | MU-MRJU | Till (Dmm(s)); fissile, with numerous inclusions of underlying peat, and other sediment. |
| | Lowermost fluvial unit | |
| 2.0 - 2.5 (0.61 - 0.76) | Ob | Compressed peat, oxidized at base. |
| 2.5 - 3.0 (0.76 - 0.91) | MRU | Massive silt loam; varies from 0.2-0.5 feet thick. |
| 3.0 - 4.2 (0.91 - 1.28) | MUU-UU | Light silty clay loam "marl"; highly effervescent; abundant shells and organic matter. |

NOTE: The thickness of these units varies; they appear to be inset in a broad swale in the underlying silts and sands. The "shelly" silty clay loam pinches out to the west; the peat is truncated to the west as the overlying till drops in elevation.

| | | |
|---|---|---|
| 4.2 - 6.0 (1.28 - 1.83) | MUU and MOU | Silts (MUU) and sands (MOU); deformed by load structures. |
| | Lowermost diamicton unit | |
| 94.5 - 95.5 (28.8 - 29.1) | MUJU | Loam diamicton (Dms), upper portion with thin silt loam partings. |
| 95.5 - 96.0 (29.1 - 29.3) | OU | Yellowish red (5YR5/6); loam diamicton (Dms-Dmm(s)); partially iron cemented; erratic pebbles and many cobbles of Pennsylvanian substrate; abrupt lower contact; yellowish red color may be derived from Pennsylvanian; this "color band" locally is absent or is present as inclusion in UU till. |
| 96.0 - 97.2 (29.3 - 29.6) | | "Deformation" till (Dcm(s)); glacially deformed Pennsylvanian rocks; deformed, slickensided, sheared, noncalcareous diamicton; mudstone-shale matrix, with angular clasts of sandstone and shale; a few erratics; locally, angular, clast-supported diamicton. |
| | PENNSYLVANIAN Undifferentiated | |
| 97.2 - 98.2 (29.6 - 29.9) | | Brown, cemented, noncalcareous, fine-grained sandstone. |
| 98.2 - 103.7 (29.9 - 31.6) | | Poorly indurated, gray, noncalcareous, shaley mudstone and siltstone; lower contact clear, but poorly exposed. |

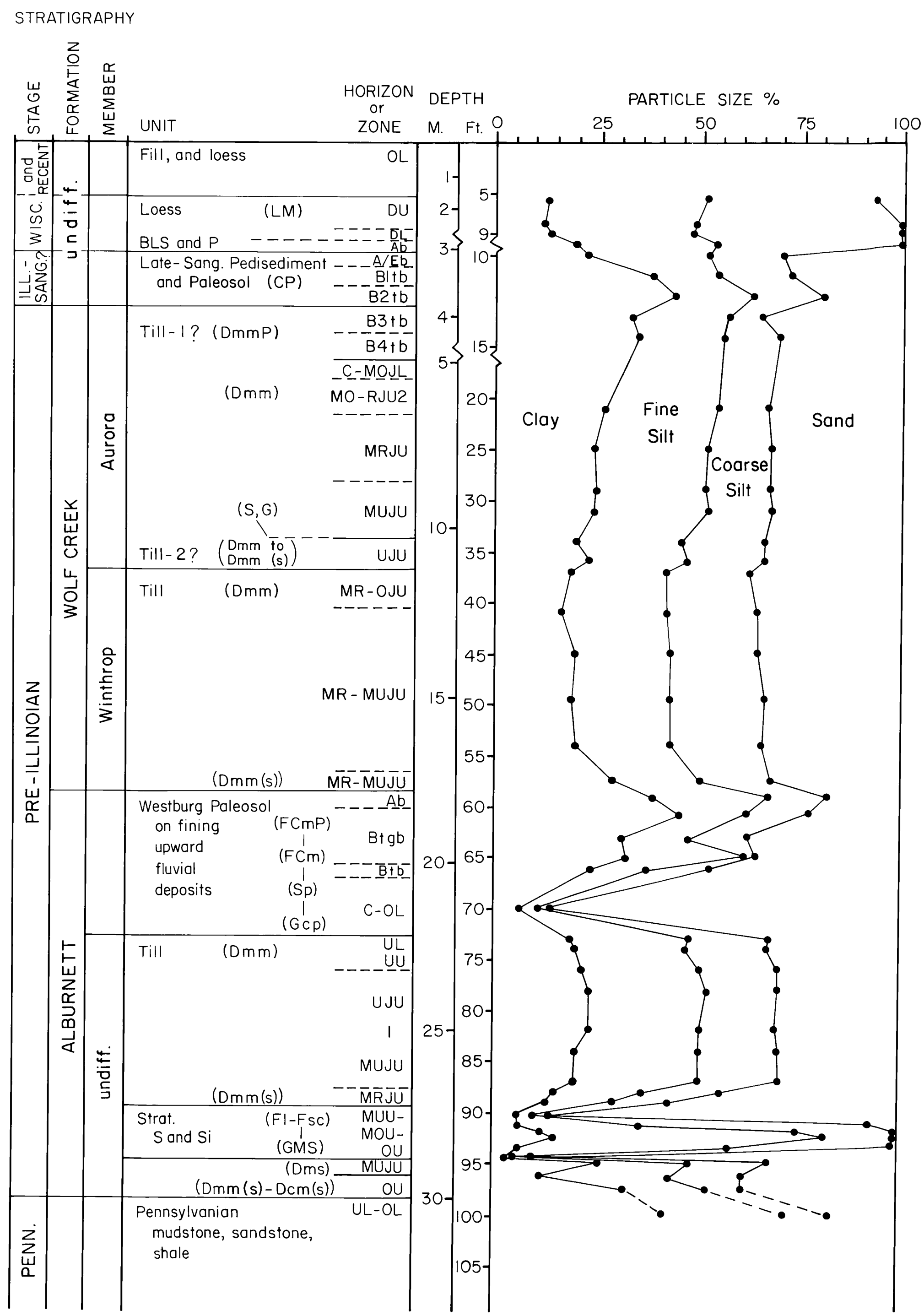



**Figure 4.** Stratigraphy and particle-size data for the 1983-84 exposure at Conklin Quarry (Section 1 on Fig. 2).

**Table 3.** Particle-size and clay-mineralogy data for the 1983-84 exposure at Conklin Quarry (adapted from Hallberg et al., 1984).

| Depth | Horizon or Zone | Particle Size - % | | | | Clay Mineralogy - % | | |
|---|---|---|---|---|---|---|---|---|
| feet (m) | | Clay | Fine Silt | Coarse Silt | Sand | Ex. | Ill. | K + C |
| | PEORIA LOESS | | | | | | | |
| 5.8 (1.8) | DU | 12.8 | 37.5 | 39.9 | 9.8 | | | |
| 8.0 (2.4) | DU | 11.9 | 37.1 | 51.6 | 0.6 | | | |
| 9.0 (2.7) | DU-DL | 12.8 | 34.1 | 52.3 | 0.8 | | | |
| | PISGAH FORMATION (BLS) Farmdale Soil (BLP) | | | | | | | |
| 9.6 (2.9) | A/Eb | 18.9 | 33.7 | 46.6 | 0.8 | | | |
| | WOLF CREEK FORMATION Late-Sangamon sediment (LSPs) Sangamon Soil (LSP) | | | | | | | |
| 10 (3.1) | Eb | 21.1 | 29.7 | 18.4 | 30.8 | | | |
| 11 (3.4) | Bt1b | 37.1 | 15.8 | 18.3 | 28.8 | | | |
| 11.8 (3.6) | Bt2b | 42.2 | 19.5 | 17.7 | 20.6 | | | |
| | (Stone line at base of unit) | | | | | | | |
| | Aurora Till Member | | | | | | | |
| 13.0 (3.9) | Bt3b | 36.8 | 18.6 | 14.0 | 30.6 | | | |
| 15.0 (4.6) | Bt4b | 34.2 | 20.7 | 13.3 | 31.8 | | | |
| 21 (6.4) | C-MO-RJU2 | 26.0 | 27.2 | 12.3 | 34.5 | 60 | 20 (trace vermiculite) | 20 |
| 25 (7.6) | MRJU | 24.1 | 26.5 | 17.0 | 32.4 | 59 | 20 | 21 |
| 29 (8.8) | MRJU | 24.8 | 25.6 | 17.3 | 32.4 | 57 | 21 | 22 |
| 31 (9.5) | MRJU | 24.6 | 26.3 | 17.1 | 32.0 | | | |
| | (Intra-Aurora till-till contact?) | | | | | | | |
| 34 (10.4) | UJU | 18.7 | 24.9 | 21.1 | 35.3 | 64 | 15 | 21 |
| 36 (10.9) | UJU | 22.7 | 22.8 | 20.2 | 34.3 | 66 | 14 | 20 |
| | Winthrop Till Member | | | | | | | |
| 36.4 (11.1) | MR-OJU | 18.0 | 22.2 | 22.6 | 37.2 | 64 | 17 | 19 |
| 41 (12.5) | MRJU | 15.7 | 24.7 | 23.0 | 36.6 | 60 | 20 | 20 |
| 45 (13.7) | MR-UJU | 19.4 | 22.2 | 22.3 | 36.1 | 62 | 16 | 22 |
| 54 (16.5) | MR-UJU | 19.3 | 22.1 | 23.0 | 35.6 | 56 | 19 | 25 |
| | (Winthrop with sheared inclusions of substrate) | | | | | | | |
| 58 (17.7) | MR-UJU | 27.2 | 22.4 | 17.4 | 33.1 | 60 | 19 | 21 |
| | ALBURNETT FORMATION Uppermost fluvial unit Westburg Soil | | | | | | | |
| 58.4 (17.8) | A/Bb | 37.4 | 28.3 | 14.5 | 19.8 | | | |
| 60 (18.3) | Btg1b | 43.4 | 15.9 | 16.8 | 24.0 | (67) | (13) | (20) |
| 63 (19.2) | Btg2b | 29.7 | 15.1 | 15.6 | 39.6 | Weathered; broad smectite; trace | | |
| 65 (1.98) | Btg3b | 30.8 | 27.7 | 4.4 | 37.1 | vermiculite; little illite apparent. | | |
| 66 (20.1) | Btb | 22.2 | 13.5 | 16.0 | 48.3 | (49) | (12) | (39) |
| 70 (21.3) | OL | 6.8 | 4.2 | 2.9 | 86.1 | | | |

**Table 3.** (continued)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Uppermost diamicton unit** | | | | | | | |
| 74 (22.6) | UU | 17.1 | 28.9 | 20.5 | 33.5 | 34 | 30 | 36 |
| 75 (22.9) | UU | 18.5 | 27.3 | 20.1 | 34.1 | 38 | 24 | 38 |
| 76 (23.2) | UU | 20.2 | 28.9 | 19.8 | 31.0 | | | |
| 78 (23.8) | UJU | 22.2 | 28.9 | 18.0 | 31.9 | 39 | 25 | 36 |
| 82 (25.0) | UJU | 22.4 | 26.5 | 18.2 | 32.9 | 36 | 28 | 36 |
| 84 (25.6) | UJU | 19.0 | 29.4 | 19.9 | 31.7 | 32 | 30 | 38 |
| 87 (26.5) | MUJU | 18.3 | 30.5 | 20.0 | 31.2 | 40 | 24 | 36 |
| | (Till with sheared inclusions) | | | | | | | |
| 88 (26.8) | MR-MUJU | 13.9 | 20.1 | 19.8 | 46.2 | 36 | 28 | 36 |
| 88.4 (26.9) | MR-MUJU | 12.9 | 14.8 | 13.9 | 58.4 | | | |
| | Lowermost fluvial unit | | | | | | | |
| 88.6 (27.0) | MOU | 5.9 | 3.1 | 3.9 | 87.1 | | | |
| 88.7 (27.1) | MUU | 6.5 | 23.5 | 62.5 | 7.5 | 29 | 22 | 56 |
| 90 (27.4) | UU | 6.6 | 27.9 | 58.0 | 8.0 | 34 | 21 | 45 |
| 91 (27.7) | UU | 11.1 | 61.4 | 26.7 | 0.7 | 32 | 18 | 50 |
| 92 (28.0) | UU | 14.1 | 64.9 | 20.6 | 0.5 | 33 | 20 | 47 |
| 93 (28.4) | UU | 6.8 | 48.9 | 42.7 | 1.6 | 34 | 22 | 44 |
| 94.1 (28.7) | OU | 2.3 | 0.1 | 6.0 | 91.6 | | | |
| | Lowermost diamicton unit (stratified) | | | | | | | |
| 95 (29.0) | MUJU | 24.4 | 22.3 | 19.0 | 34.3 | 42 | 25 | 33 |
| | (with yellowish-red Pennsylvanian inclusions) | | | | | | | |
| 95.8 (29.2) | OU-UU | 11.1 | 27.3 | 18.3 | 40.3 | -- | (41) | (55) |
| | | | | | | | trace chlorite | |
| | (diamicton-deformed Pennsylvanian) | | | | | | | |
| 96.5 (29.4) | UL-UU | 30.3 | 19.9 | 9.2 | 40.6 | -- | (45) | (55) |
| | | | | | | | trace chlorite | |
| | PENNSYLVANIAN undifferentiated mudstone | | | | | | | |
| 99 (30.2) | UL | 39.3 | 31.5 | 11.1 | 18.1 | -- | (42) | (58) |
| | | | | | | | trace chlorite | |
| | (Samples taken laterally from main section) | | | | | | | |
| | WOLF CREEK FORMATION Aurora or Hickory Hills Till Member? | | | | | | | |
| | OL | 19.6 | 16.8 | 14.4 | 49.2 | 64 | 16 | 20 |
| | OL | 18.7 | 20.6 | 15.0 | 45.7 | 64 | 16 | 20 |
| | OJL | 19.9 | 17.9 | 15.8 | 46.4 | 62 | 17 | 21 |
| | MOJL | 20.2 | 21.3 | 18.5 | 40.0 | 68 | 14 | 18 |

**Table 4.** Summary of laboratory data for unweathered diamicton samples from Conklin Quarry (adapted from Hallberg et al., 1984).

| | Particle Size - % | | | | Clay Mineralogy - % | | |
|---|---|---|---|---|---|---|---|
| | Clay mean ± s.d. | Silt mean ± s.d. | Sand mean ± s.d. | | Ex. mean ± s.d. | Ill. mean ± s.d. | K + C mean ± s.d. |
| | | | WOLF CREEK FORMATION | | | | |
| | | | Hickory Hills Till Member (or Aurora?) | | | | |
| | | | (Note: only 5 of these samples were calcareous) | | | | |
| N = 16 | 22 ± 4 | 34 ± 5 | 43 ± 6 | N= 20 | 64 ± 3 | 16 ± 2 | 20 ± 2 |
| | | | Aurora Till Member | | | | |
| | | | (above intra-Aurora contact) | | | | |
| N = 14 | 24 ± 3 | 42 ± 3 | 34 ± 5 | N = 11 | 63 ± 4 | 17 ± 2 | 20 ± 3 |
| | | | (below intra-Aurora contact) | | | | |
| N = 8 | 20 ± 1 | 42 ± 3 | 37 ± 2 | N = 10 | 65 ± 4 | 16 ± 2 | 20 ± 3 |
| | | | Winthrop Till Member | | | | |
| N = 15 | 23 ± 4 | 42 ± 5 | 35 ± 4 | N = 21 | 62 ± 5 | 16 ± 3 | 22 ± 3 |
| | | | ALBURNETT FORMATION | | | | |
| N = 19 | 21 ± 3 | 43 ± 6 | 36 ± 6 | N = 34 | 37 ± 4 | 26 ± 4 | 37 ± 6 |

mixed clay mineralogy typical of the Alburnett Formation. Diamicton overlying Devonian carbonates also had mixed mineralogy typical of the Alburnett Formation.

***Secondary Pedogenic and Weathering Properties.*** This unit was unweathered. All facies had a dark gray, unoxidized matrix.

***Lowermost Fluvial Unit***

***Facies.*** The lowermost fluvial unit has varied from 2 to 8 m in thickness, but has generally been thin. The unit is absent in the present exposure, truncated by glacial erosion associated with the uppermost Alburnett diamicton unit. The unit consisted of a generally fining upward sequence of fluvial and ox-bow-lake deposits. A lag gravel at the base graded upward to thin beds of massive and ripple-drift cross-laminated sand (facies Sr) that, in turn, graded upward to silts (facies Fl, Fsc, and Fm) and laminated silt and sand (Fig. 2). Local swales on top of this fluvial sequence preserved about 1 m of ox-bow-lake deposits capped by a thin, highly compacted, fossiliferous peat. Biota in the upper part of this unit comprise the Angerer Local Biota of Baker et al. (1984)(discussed below). Laminated silt and sand in the upper 0.5 m of the unit were complexly deformed into various 'soft-sediment' deformation structures that indicate compaction and dewatering (Lowe and LoPiccolo, 1974; Lowe, 1975, 1978), including diapiric 'soft-sediment' folds, water-escape tubes and sheets extending up to and along the contact with the overlying diamicton, dish structures, and deformed contacts. These structures are related to compaction resulting from the glacial overriding that deposited the upper diamicton. Locally, there are overturned diapiric folds and low-angle thrust faults which are associated with glacial overriding. The strain indicated by these local deformation structures is low. The two thrust faults present in 40 m of exposure in 1986 had measured displacements of 5 and 50 cm, respectively.

***Mineralogy.*** The clay mineralogy of these fluvial deposits is typical of that for the Alburnett Formation (Table 3; see also Hallberg et al., 1984).

***Secondary Pedogenic and Weathering Properties.*** Sands in this sequence are oxidized, but the finer grained deposits are unoxidized or reduced. Locally the deposits are leached.

**Table 5.** Bulk-density data for massive diamictons at Conklin Quarry (adapted from Hallberg et al., 1984).

| | Density - g/cc mean | range |
|---|---|---|
| | WOLF CREEK FORMATION | |
| | Hickory Hills Till Member (or Aurora?) | |
| N = 11 | 1.82 | 1.76 - 1.88 |
| | Aurora Till Member | |
| N = 10 | 1.83 | 1.80 - 1.98 |
| | Winthrop Till Member | |
| N = 4 | 1.96 | 1.89 - 1.98 |
| | ALBURNETT FORMATION | |
| N = 9 | 2.04 | 1.97 - 2.11 |

***Paleoenvironmental Interpretations from Fossil Biota.*** Preliminary study of fossil pollen and biota (Baker et al., 1984) in a thin fine-grained pod near the top of the fluvial sequence (Angerer Local Biota) indicated that the site had been a shallow weedy pond, probably an ox-bow lake, surrounded by an open, conifer-dominated forest resembling the coniferous forest-prairie border in southern Alberta, Saskatchewan, and Manitoba today.

The pollen was dominated by arboreal pollen, primarily spruce, larch, and pine, with low percentages of birch and oak. Sedge pollen was the most abundant herb, but grass and sagebrush were also present. Pollen from aquatic plants included water-milfoil and cattail or bur-reed; also present were spores of scouring rush, a plant that grows along pond margins. Plant macrofossils were almost entirely aquatic species, including pondweeds, sedges, and water-milfoil.

Fifteen taxa of molluscs were identified: 8 aquatic snails, 2 bivalves, and 5 terrestrial snails. The aquatic snails were the most abundant, and their fossil assemblage was similar to that inhabiting shallow, semi-permanent, mud-bottomed ponds with abundant aquatic vegetation in the cool, moist boreal forest of southern Alberta, Saskatchewan, and Alberta. Terrestrial snails were rare, but they were all taxa that inhabit moist, open ground.

### *Uppermost Diamicton*

***Facies.*** The uppermost Alburnett diamicton unit is the oldest Quaternary deposit in the 1991-92 exposure (Fig. 3). In previous exposures it has usually been 2 to 4 m in thickness, but ranged up to 8 m in thickness. The present exposure reveals the thickest uppermost diamicton yet observed, over 10 m. The unit is dominated by massive, dense (Table 5) diamicton with uniform matrix properties that have varied little vertically and laterally over hundreds of meters of exposure (Fig. 4 and Table 3; see also Hallberg et al., 1984). The contact with underlying fluvial deposits was generally planar and abrupt, although portions of the bed locally undulated downward either because of erosion or differential compaction. Diapiric soft-sediment folds in the underlying fluvial sediment were locally truncated at the contact with the overlying diamicton. Water-escape tubes up to and along the basal contact with the diamicton indicated that dewatering and compaction of the underlying fluvial sediments was related to glacial overriding.

Numerous features indicated deposition at the base of an actively moving glacier. In previous exposures, the lowermost 0.2 to 1 m commonly had various shear structures and block inclusions of underlying peat and fluvial sediment, and a pronounced fissility [facies Dmm(s)]. The fissility consisted of irregular plates 5 to 20 cm long and 0.5 to 2 cm thick along which incipient oxidation had developed. Striations on a bedrock knob were oriented 132°-312° indicating glacial flow from the NW (Table 6). Locally, cobbles at the base of the diamicton were embedded ("lodged") into the underlying fluvial deposits, and

**Table 6.** Directional indicators associated with the uppermost diamicton unit of the Alburnett Formation at Conklin Quarry (from the 1986 exposure).

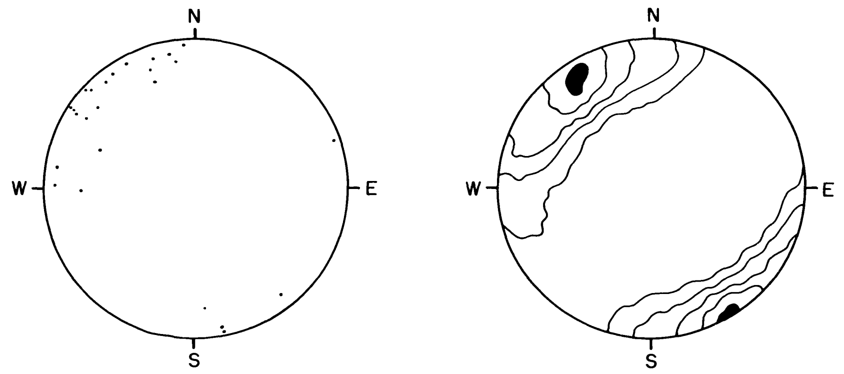
| | | | |
|---|---|---|---|
| | | **Orientation** | |
| Bedrock striations | | 312° | |
| Diamicton-filled grooves behind cobbles imbedded at basal contact | | 309° and 320° | |
| A-axis of keel-shaped cobble imbedded at basal contact | | 337° | |
| Pebble fabrics: $S_1$, orientation and significance | **Az.** | **Dip** | **Sig.** |
| Site 1; fissile diamicton by keel-shaped cobble | 320° | 8° | 0.77 |
| Site 2; massive diamicton by block inclusion of peat | 301° | 4° | 0.90 |
| Site 3; massive diamicton | 322° | 7° | 0.89 |
| Twig fragment fabric: site 1, $S_1$ orientation and significance | 314° | 8° | 0.85 |

diamicton-filled grooves behind two of the embedded clasts were oriented at 309° and 320° (Table 6). Pebble fabric measurements (Fig. 5; Table 6) also showed strongly oriented fabrics at all levels ($s_1$ eigenvalues ranging from 0.77 to 0.90) with the direction of maximum clustering ($s_1$ eigenvector) also to the NW, ranging from 301° to 322°. Twig fragments, probably eroded from the peat at the top of the underlying fluvial deposits, were common at the base of the diamicton, but gradually disappeared within 2 m of the diamicton base. The twig fabric was identical to that of the pebbles: it was also strongly oriented ($s_1$ significance value of 0.85) to the northwest ($s_1$ eigenvector of 314 degrees)(Fig. 5).

***Mineralogy.*** The uppermost diamicton is characterized by mineralogic properties that are characteristic of the Alburnett Formation, and which have little variation either laterally or vertically (Fig. 4; Tables 3 and 4; see also Hallberg et al., 1984).

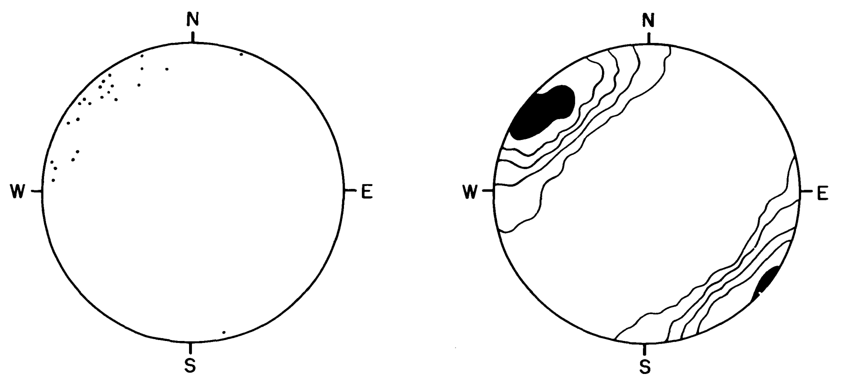
***Secondary Pedogenic and Weathering Properties.*** Secondary properties in this unit have varied as the outcrops have changed. In exposures prior to 1991-92, the unit was truncated by the uppermost Alburnett fluvial unit and the diamicton was unoxidized throughout, although there were minor variations with depth. The very top was leached, associated with soil development and leaching of the overlying fluvial unit, and fissile plates at the base of the diamicton were oxidized along fractures. At the present exposure, the valley margin of the overlying fluvial unit is exposed, and south of this margin (left side of Fig. 3) thicker Alburnett Formation diamicton is preserved. The top of the thicker diamicton has been truncated by later glacial and subaerial erosion (from north to south, successively by the Winthrop and Aurora till members of the Wolf Creek Formation, and the Late Sangamon erosion surface). Although the soil that developed on this surface (the Westburg Soil) has been truncated, the underlying weathering-zone sequence associated with it is preserved. Successively from the upper contact with the Wolf Creek Formation deposits, these weathering zones include MOL, MOJU2, MOJU, UJU, and UU (Fig. 3). The unit is deeply oxidized (over 7 m).

Vertical joints (the J designation in MOJU2, MOJU, and UJU; see weathering zone sidebar) form a complex network. The oldest joints form an irregular polygonal network in which discontinuous joints form triple intersections at various angles (Pollard and Aydin, 1988) and the size of the polygons progressively increases with depth. These joints have rinds 40 to 60 mm wide that consist of a light gray, reduced central area 1 to 2 mm wide and outer rinds on each side stained




Prolate Pebbles
n = 25

| | Az. | Dip | Sig. |
|---|---|---|---|
| $S_1$ | 320° | 8° | 0.77 |
| $S_2$ | 229° | 7° | 0.20 |
| $S_3$ | 101° | 79° | 0.03 |




Wood Fragments
n = 23

| | Az. | Dip | Sig. |
|---|---|---|---|
| $S_1$ | 314° | 8° | 0.85 |
| $S_2$ | 224° | 2° | 0.14 |
| $S_3$ | 122° | 82° | 0.01 |

**Figure 5.** Fabrics of diamictons and twigs at the base of the uppermost Alburnett diamicton exposed in 1986.

reddish brown with secondary iron-oxides. Average width across the irregularly shaped polygons increases downward from approximately 30 cm near the upper part of the preserved MOJU weathering zone to about 100 cm in the lower part. They extend down into the upper part of the unoxidized diamicton (UJU weathering zone). In the MOJU weathering zone, the polygons are further broken up by thin (2 to 5 mm wide), light gray, reduced vertical joints with spacings ranging from 10 to 100 mm. These younger joints are nonorthogonal and discontinuous. Joints are opening fractures (Pollard and Aydin, 1988). The polygonal geometry in this unit indicates that they formed by contraction, in this case caused by desiccation (shrink-swell) in the oxidized (unsaturated) MOJU weathering zone that progressed from the former landsurface (most fractured) downward to the unoxidized (saturated) UU weathering zone.

### *Uppermost Fluvial Unit*

***Facies.*** The facies of this unit have varied with the position of the outcrops as quarrying has progressed. Successive exposures have indicated that the unit occurs in a shallow valley trending approximately NW-SE across the central part of the quarry site. The present outcrop (Fig. 3) exposes the southwestern margin of the valley. The combined thickness of the unit has usually varied from 4 to 6 m. A cobble and boulder lag is usually developed on the underlying diamicton and it is overlain by two increments: a lower sandy and pebbly sand increment, and an upper fine-grained increment. The lower increment has consisted of 2 to 5 m of cross-bedded sand and pebbly sand; the sands were thicker and coarser near the center of the former channel. Large spruce logs, nearly the size of telephone poles, have occasionally been observed at the base of the sands. The present outcrop exposes the southern edge of this valley, and the sands and the cobble lag pinch out towards the valley margin (see left side of Fig. 3). The upper increment consists of a fining-upward sequence of poorly sorted fine-grained sediment (sandy clay loam, clay loam, silty clay loam, and silty clay textures, with occasional pebbles interspersed) that has varied from 3 to 4 m in thickness. These materials are interpreted to be overbank and colluvial deposits. The Westburg Soil (see below) formed in the upper part of this increment. The contact with diamicton of the overlying Winthrop Till Member of the Wolf Creek Formation is abrupt. Locally the Westburg Soil has been truncated, and in some places it has been deformed into massive sheared and slickensided blocks. Small block inclusions of the paleosol are locally found in the basal part of the overlying diamicton.

***Mineralogy.*** The clay mineralogy varies because of pedogenic alteration. In the solum, the smectite peak is broad, and total smectite percentages are high. The clay mineralogy progressively changes with depth; from the lower B horizon to the base of the unit, the clay mineralogy is typical of that for the Alburnett Formation (Table 3).

***Secondary Pedogenic and Weathering Properties.*** The Westburg Soil is a cumulic, poorly drained, morphologically well expressed soil developed in the top of the upper increment. It has an argillic B horizon with continuous clay coatings and strong soil structure. The strong structure may be related, in part, to the fining-upward sedimentology and to later compaction by overriding glaciers. The lateral equivalent of this soil on higher landscape positions, developed in the uppermost diamicton, has been truncated by later glacial erosion by Wolf Creek Formation tills. Even so, the deep weathering preserved on higher landscape positions and the relatively thick, well-expressed O-A-Bt-C horizon sequence of this soil indicate the Westburg Soil in the alluvium is of interglacial rank.

In previous exposures, a thin, compressed O horizon (peat and mucky silty clay loam) locally filled small channels cut into the Westburg Soil (Fig. 2). Little pollen was preserved in the peat, but fragments of spruce wood were present. The spruce probably grew as climate became colder prior to the glacial advance associated with the overlying Winthrop Till Member of the Wolf Creek Formation.

Peaty O horizons are commonly associated with buried soils developed in alluvium of the pre-Illinoian sequence. Invariably, pollen spectra from the peats are dominated by taxa indicating boreal conditions. These O horizons probably developed in proglacial settings during advance of the glacier that deposited the overlying diamicton. If this is the case, the O horizons and associated paleoecologic record do not necessarily reflect the range of environmental conditions under which the soil profile beneath the O horizon developed.

## WOLF CREEK FORMATION

The Wolf Creek Formation is the youngest pre-Illinoian formation in Iowa, and it is differentiated from the underlying Alburnett Formation by stratigraphic position and by higher percentages of smectite (mean of 61% vs. 43%; Table 1). In complete sequences, the Wolf Creek Formation is composed of 3 members, from oldest to youngest, the Winthrop, Aurora, and Hickory Hills till members, distinguished on the basis of stratigraphic position and various laboratory data (Hallberg, 1980a; Hallberg et al., 1980), including subtle differences in texture (Table 7). The Winthrop and Aurora till members are exposed at Conklin Quarry. The Hickory Hills Till Member may have been present in older exposures (Fig. 2; Tables 2 and 3), but truncation by the Late Sangamon erosion surface and pedogenic alteration by the Sangamon Soil prevented conclusive identification.

### *Winthrop Till Member*

***Facies.*** As quarry operations have progressed, the Winthrop Till Member has varied in thickness from 5 to 10 m. In the present exposure, it is up to 6 m thick, but has been glacially truncated by the overlying Aurora Till Member near the center of the exposure.

Diamicton facies in the Winthrop Till Member are like those in the Alburnett Formation, and indicate subglacial deposition. A basal zone contains abundant block inclusions, smears, and smudges of substrate materials, including peat, wood, paleosol, and Pennsylvanian mudstone. This zone grades upward to dense, massive diamicton (facies Dmm) with uniform matrix properties (Fig. 4; Tables 3, 4, and 5).

The upper diamicton surface of the Winthrop Till Member is truncated. In most places it has been truncated by the overlying Aurora Till Member. In earlier exposures, local fluvial channel fills capped with peats were present (Fig. 2). These channel fills were composed of fining-upward sequences (facies S-F) successively comprised of planar-bedded sand, interbedded fine sand and silty clay loam, massive silt

**Table 7.** Summary of particle-size data for till members of the Wolf Creek Formation in eastern Iowa (from Hallberg et al., 1984).

| | Particle Size - % | | |
|---|---|---|---|
| | Clay mean ± s.d. | Silt mean ± s.d. | Sand mean ± s.d. |
| | | Hickory Hills Till Member | |
| N = 283 | 22 ± 4 | 34 ± 4 | 44 ± 4 |
| | | Aurora Till Member | |
| N = 197 | 22 ± 4 | 40 ± 4 | 38 ± 5 |
| | | Winthrop Till Member | |
| N = 60 | 26 ± 4 | 41 ± 4 | 33 ± 4 |

loam and silty clay loam, and, locally, peat. The upper part of these sequences had been altered by incipient soil formation (see below). Near the center of the present outcrop is a lateral equivalent of one of these channel fills (Fig. 3). It has not yet been studied in detail, but includes thinly bedded and laminated sand and silt in which a weakly expressed soil has developed.

***Mineralogy.*** The clay mineralogy of the Winthrop Till Member (Tables 3 and 4) is typical of the Wolf Creek Formation. The expandable clay mineral content is significantly higher than that of the underlying Alburnett Formation (mean: 62% vs. 37%), and the corresponding kaolinite-and-chlorite content is significantly less (mean 22% vs. 37%)(Table 4).

***Secondary Pedogenic and Weathering Properties.*** A weakly expressed example of the Franklin Soil (Hallberg, 1980b) is developed in the fluvial deposits locally incised into the Winthrop Till Member. At Conklin Quarry, horizon sequences comprising the soil have varied from O-A-C to A-C to A-Bwg-C. Only incipient soil development has taken place; even in the most morphologically well expressed profile (A-Bwg-C), the cambic B horizon was gleyed and had only weak to moderate grade soil structure. Locally, a compressed peat or muck (O horizon) capped the paleosolum. Little well preserved pollen was present, but a few spruce, chenopod, and grass pollen grains were identified. The Franklin Soil would appear to be a first- or lower-order interstadial soil in the terms defined by Follmer (1983).

Although the equivalent soil on higher landscape positions in the Winthrop diamicton has been truncated, a full set of associated weathering zones has been preserved. Successively from the truncated upper surface, these include the MOJU, MRJU, UJU, and UU weathering zones (Fig. 3). As much as the upper 5 m have been oxidized, and jointing extends down into the upper part of the unoxidized weathering zone.

Evaluating the relative importance of stratigraphic breaks represented by soils in the pre-Illinoian sequence is not an easy task. Most soil profiles buried by pre-Illinoian glacial diamicton are developed in alluvium in paleovalley settings. Direct comparison of their horizon sequence with 'Quaternary standards' such as the Sangamon or Modern soil, developed on relatively stable upland landforms, is probably not a valid approach for determining relative rank (interglacial, first-order interstadial, etc.). Alluvial environments contain a host of time-independent facies that strongly affect the morphology of soils developed in them. In addition, weathering zones, especially the oxidized and leached zones, are usually developed to much shallower depths in valley environments. These considerations cast doubt on relative rankings based on direct comparisons of soil profiles and weathering zones developed in upland and valley positions.

The Franklin Soil in Conklin Quarry exemplifies some of these complexities. Based solely on the preserved soil profile (developed in alluvium) a first- or lower-order interstadial rank is suggested. On the other hand, a 5 m thick truncated weathering profile (associated with a valley wall or upland) located lateral to the Franklin Soil suggests significant landscape development and weathering of the Winthrop Till Member.

### *Aurora Till Member*

***Facies.*** The Aurora Till Member has usually been one of the thickest pre-Illinoian units at Conklin Quarry, varying from 6 to 12 m in thickness. The maximum thickness in the present exposure is just over 11 m (Fig. 3). A discontinuity called the 'intra-Aurora contact' (IAC on Figs. 2 and 3) occurs within the Aurora Till Member. In previous exposures a discontinuous zone 1 to 3 m thick of water seepage and minor color (weathering zone) changes occurred in the diamicton below this contact. The zone was composed of thin (0.03 to 0.3 m thick), discontinuous, elongate (0.1 to 1.54 m long) sand-and-gravel stringers in diamicton with prominent, thin fissile partings. The intra-Aurora contact was abrupt, marked by color changes above and below, but there was no significant difference in texture or mineralogic composition in the diamictons (Table 3). At the present exposure, this lower zone is preserved only as an irregular unit up to 2 m thick along the southern two-thirds of the outcrop (Fig. 3). It has not been studied in detail, but observed facies include massive diamicton (Dmm) and diamicton with thin stringers of sand and pebbly sand (facies Dms). The diamicton has a blocky secondary structure, and is a reduced dark gray (5Y 4/1) with dark brown (10YR 4/4) coatings on block faces that contrasts sharply with the very dark gray to black (N 3/0 to N 2/0) unoxidized diamicton above the intra-Aurora contact. Because of poor outcrop conditions throughout the Fall of 1991, the IAC could not be studied in detail, but it is not planar. At least locally, there are small troughs a few meters wide and less than 1 m deep; these are not shown on the cross-section (Fig. 3). The unit below the IAC may represent a change in subglacial deposition or a minor retreat and readvance of the ice (Hallberg et al., 1984). Elsewhere in eastern Iowa, various till members (such as the Aurora) are locally comprised of multiple diamicton units with similar relationships, but there is no evidence that these represent major unconformities (with a major paleosol, etc.) of interglacial nature (Hallberg, 1980a, b).

Above the IAC, the diamicton resembles that of previously described diamicton units: the lowermost portion includes various shear and deformation structures, and contains common block inclusions and smudges of local substrate; this lowermost zone grades upward to massive, uniform diamicton (facies Dmm). Moderately large, discontinuous sand lenses occur at a distinct horizon within the diamicton (Fig. 3). Structures and contacts of stratified sediment within diamictons are commonly used to make process interpretations (e.g., Levson and Rutter, 1989), but lenses in the Aurora Till Member at Conklin Quarry are difficult to interpret because sedimentary and deformation structures cannot be determined in the massive, well sorted sands, and contacts with the enclosing diamicton are obscured by thick cementation with secondary carbonate (typically the boundaries are ringed with secondary carbonate cement 1 to 5 cm thick). The geometry of the lenses, however, provides a genetic clue. None of the lenses show evidence of shear truncation, some have convex upper surfaces like the "plano-convex" lenses Shaw (1982) interprets to form in association with melt-out till, and some are gently tilted, but otherwise have an undisturbed, channel-like geometry. These lenses appear to have formed as glaciofluvial fills in englacial or subglacial channels while melt-out till formed from adjacent debris-rich ice (Shaw, 1982).

The top of the Aurora Till Member has been truncated by a subaerial erosion surface, the Late Sangamon erosion surface (Ruhe et al., 1967; Ruhe, 1969). This surface is marked by a well expressed stone line, a lag gravel left as fine material in the till matrix is preferentially eroded (Canfield et al., 1984; Ruhe, 1959). The Sangamon Soil developed in colluvium associated with this erosion surface (Ruhe referred to this type of sediment as 'pedisediment') and the underlying till of the Aurora Till Member (see Table 2 and the section on secondary pedogenic and weathering properties below).

A thin, complex unit, truncated by the Late Sangamon erosion surface, overlay the Aurora Till Member in the 1975-76 exposure. The unit contained various sand lenses, and the diamicton was sandier than the underlying diamicton. The Sangamon Soil was developed in the top of the unit and the underlying progression of weathering zones was the predictable MOJL/MRJU/MR-UJU sequence. At the time, the origin of this unit was uncertain, and various hypotheses were presented: 1) the unit represented a readvance associated with the Aurora Till Member, 2) the unit was a supraglacial facies of the Aurora Till Member, or 3) the unit was a remnant of the Hickory Hills Till Member. Although the data are inconclusive, it is more likely that the unit was the Hickory Hills Till Member (see below).

***Mineralogy.*** The clay mineralogy of unweathered samples from the Aurora Till Member (Table 4) are characteristic of the Wolf Creek Formation (Table 1) with high percentages of expandable clay minerals and low percentages of illite.

***Secondary Pedogenic and Weathering Properties.*** The pre-Illinoian glacial sequence at Conklin Quarry is truncated by the Late Sangamon erosion surface (Ruhe et al., 1967; Ruhe, 1969; Hallberg, 1980a), an erosion surface that developed as the regional drainage network evolved. The present exposure cuts across a loess-mantled interfluve of the Late Sangamon erosion surface (Fig. 3). The Sangamon Soil, and the underlying weathering zones associated with it, developed downward from the erosion surface (or any thin overlying colluvium associated with it). [Note: previous studies, following Ruhe, 1956, referred to this soil-stratigraphic unit in relative-time terms as the Late Sangamon Paleosol; present pedostratigraphic practice is independent of time, and soil-stratigraphic units are defined on the basis of the unit which buries them. This soil-stratigraphic unit corresponds to the Sangamon Soil because it is buried by the Pisgah Formation, a unit stratigraphically (but not lithologically) equivalent to the Roxana Silt that buries the Sangamon Soil in the type area (e.g., Follmer, 1978; Willman and Frye, 1970)].

From a distance, the Sangamon Soil appears as a dark reddish band arcing across the interfluve, but the Sangamon Soil facies here vary with position across the slope (these paleosol 'facies' are analogous to soil 'series' of modern soils). Table 8 gives a description of the Sangamon Soil at the crest of the Late Sangamon erosion surface (position A on Fig. 2). At this position, the Sangamon Soil is morphologically well expressed with a thick E-Bt-C horizon sequence preserved. The soil's gradational upper boundary with overlying colluvial and eolian sediments of the Pisgah Formation reflects slow burial. No A horizon is macroscopically preserved; organic matter is not persistent after burial in well drained positions (Yaalon, 1971) because it is rapidly destroyed by oxidation, and organic-matter content was probably low anyway because soils associated with conifer forests, like that existing at the time of burial, have low organic-matter content. The E horizon is thin, and consists of weak to moderate platy soil structure, breaking to weak to moderate very fine subangular blocky structure. The argillic B horizon is over 1.5 m thick—note the clay "bulge" of the B horizon in the particle-size profile on Figure 6. The B horizon has well expressed strong subangular to angular blocky soil structure that grades downward in size from very fine to coarse (Table 8; note that strong grade soil structure is very prominent, defined as "durable peds that are quite evident in undisturbed soil;" Soil Survey Staff, 1975). In the main part of the B horizon, peds are continuously coated with illuvial clay, and in the lower part of the horizon, larger, joint-like structural units are coated with very dark gray secondary manganese-oxide coatings.

Color has often mistakenly been used to relate soils to climate and/or time (Ruhe, 1965). The Sangamon Soil here has not been studied in detail, but micromorphological study by Thompson and Soukup (1990) of a Sangamon Soil in western Iowa reveals that the reddish color is primarily related to secondary iron oxides that coat, and therefore are younger than, the secondary clay coatings on soil peds. This led Thompson and Soukup to suggest that the soil's reddish color post-dates burial, and results from translocation of iron weathered from the overlying Wisconsinan loesses. While the micromorphology of the Sangamon Soil at Conklin Quarry has not been studied, the suggestion that the reddish color results from post-burial iron translocation is a reasonable possibility that needs further investigation.

Below the Sangamon Soil solum, there is a predictable succession of weathering zones with depth: MOJL, MOJL2, MOJU2, MOJU, MRJU, UJU, and UU. The Aurora Till Member is deeply oxidized, with oxidation locally extending to depths over 9 m (30 ft). Leaching extends 0.5 to 1 m below the Sangamon Soil solum. Large, hard secondary carbonate nodules occur at the base of this leached zone and extend for about 1.5 m into the calcareous diamicton. Zones of secondary carbonate up to 5 cm wide discontinuously cement joints and some of the joint intersections in the diamicton. The horizon of sand lenses in the Aurora Till Member occurs at or near this zone of secondary carbonates, and contacts between the till and the lenses are commonly cemented with secondary carbonate several centimeters thick. All of this secondary carbonate was derived from the dissolution of primary carbonate minerals in the Sangamon Soil and reprecipitation with depth.

Vertical joints (the J designation in MOJL, MOJL2, MOJU2, MOJU, MRJU, and UJU) extend from the Sangamon Soil into the top of the unoxidized, unleached diamicton of the Aurora Till Member. Locally, where the member is thin, these joints extend all the way through thin, unoxidized, unleached diamicton; a few of these joints extend downward into the underlying stratigraphic unit, but most end at the base of the till member. The vertical joints form an irregular polygonal network. Joint frequency varies spatially with depth from the Late Sangamon paleolandsurface. At a site in the MOJU zone almost 8 m (25 ft) below the top of the Sangamon Soil (site 1 on Fig. 7), joint spacings range from 2-75 mm with a mean of 26 mm. Near the

**Table 8.** Description of buried Sangamon Soil on crest of paleo-interfluve at Conklin Quarry (site A, Fig. 2; particle-size profile shown on Fig. 6). Description by G.R. Hallberg, S. Esling, and T. Bicki (adapted from Hallberg et al., 1984).

| Depth meters | Horizon or Zone | Description |
|---|---|---|
| | PEORIA LOESS | |
| 0 - 0.25 | MOU | Mottled yellowish brown (10YR5/4) silt loam; common fine mottles; massive; clear, smooth lower boundary; few snail shells. |
| | PISGAH FORMATION<br>Farmdale Soil | |
| 0.25 - 0.37 | Eb | Brown (10YR5-4/3) silt loam (more sand than above); common faint yellowish brown (10YR5/4-6) mottles, few fine light gray (10YR7/1) grainy silt coats (silans); weak thin platy, breaking to weak very fine subangular blocky; common fine root tubules; friable; few fine charcoal flecks; clear, smooth lower boundary. |
| | WOLF CREEK FORMATION<br>Late Sangamon sediment<br>Sangamon Soil | |
| 0.37 - 0.50 | 2Eb | Mixed reddish yellow (7.5YR6-5/6) to yellowish brown (10YR6-5/6) loam; moderate thin platy breaking to moderate very fine subangular blocky; common moderate silt coats (as above), common thin strong brown (7.5YR4-5/6) coatings on plates and tubules; few thin discontinuous clay films; very friable; few fine charcoal flecks; clear, smooth lower boundary. |
| 0.50 - 0.59 | 2Bt1b | Strong brown (7.5YR5/6) clay loam; common fine dark brown (7.5YR4/4-6) mottles and coatings; moderate fine subangular blocky; thin to medium discontinuous clay films, few fine silt coats; firm; few fine charcoal flecks; gradual lower boundary. |
| 0.59 - 0.70 | 2Bt2b | Dark brown (7.5YR4/4) clay; common fine strong brown (7.5YR5/6), yellowish red (5YR5/6), and yellowish brown (10YR5/4-6) mottles; strong fine subangular blocky; thin nearly continuous clay films, continuous moderate films on vertical tubules; few light gray (10YR7/1) and yellowish brown (10YR5/6) silt coats; firm; few charcoal flecks; gradual boundary. |
| 0.70 - 0.76 | 2Bt3b | Stone line (gravelly clay loam) at contact between units. |
| | Aurora (or Hickory Hills) Till Member<br>Sangamon Soil (continued) | |
| 0.76 - 0.89 | 3Bt4b | Mottled dark brown (7.5YR4/4), strong brown (7.5YR5/6), yellowish red (5YR4/6), dark yellowish brown (10YR4/4) clay with some pebbles; few fine red (2.5YR4/6 and 3/6) mottles; very strong, fine subangular to angular blocky structure; continuous thick clay films; very firm; gradual lower boundary. |
| 0.89 - 1.11 | 3Bt5b | As above; with few, medium, dark gray and gray mottles and coatings; slickensided pressure faces on thick clay coatings along vertical cleavage planes; abrupt lower boundary. |
| 1.11 - 1.18 | 3Bt6b | Dark yellowish brown (10YR4-5/4) and light olive brown (2.5Y5-4/4) heavy clay loam with some pebbles; common fine and medium strong brown (7.5YR4/6 and 5/6-8) and few medium yellowish red (5YR4/6) mottles; strong medium and fine subangular to angular blocky structure; nearly continuous moderate clay films; some peds with bare interiors; firm; common pressure faces on vertical cleavage planes; gradual lower boundary. |
| 1.18 - 1.40 | 3Bt7b | Light olive brown (2.5Y5/4) clay loam with some pebbles; common brown and red mottles as above; strong medium subangular blocky, breaking to moderate fine subangular blocky; nearly continuous thin clay films on medium peds, common thin coatings on fine peds; firm; clear, wavy lower boundary. |

**Table 8.** (continued)

| | | |
|---|---|---|
| 1.40 - 1.69 | 3Bt8b | Yellowish brown (10YR5/6) clay loam with some pebbles; common strong brown (7.5YR5/6) mottles and coatings; common, coarse, thick, very dark gray (5YR3/1) manganese-oxide and clay coatings on larger structural units; strong medium, breaking to weak fine subangular blocky structure; common thin clay films; clear, wavy lower boundary. |
| 1.69 - 2.04 | 3BCtb | Yellowish brown (10YR5/6) heavy loam with pebbles; common manganese-oxide coatings as above; moderate medium to coarse subangular blocky; common thin clay films; diffuse, irregular boundary. |
| 2.04 - 2.50 | 3C-MOJL | Dark yellowish brown (10YR4/4) loam with pebbles; common yellowish brown (10YR5/6-8), brown (10YR5/3), strong brown (7.5YR4-5/6), and pale olive (5Y6/4 mottles; moderate coarse angular blocky to massive; firm; few manganese-oxide and clay coatings; brown mottles along vertical joints. |

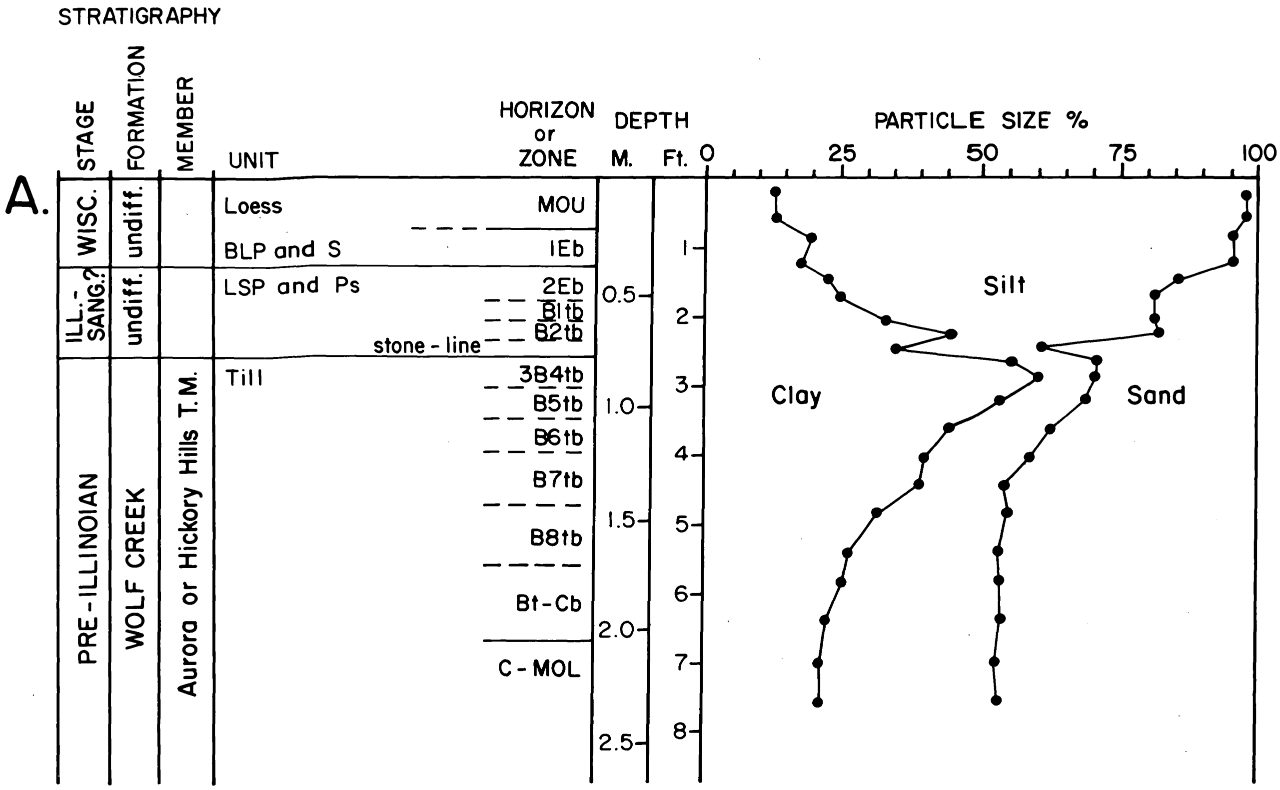



**Figure 6.** Stratigraphy and particle-size data for a Sangamon Soil profile on the 1983-84 interfluve crest at Conklin Quarry (site A on Fig. 2).

top of the underlying unoxidized (UJU) zone at a depth of about 10.5 m (35 ft; site 2 on Fig. 7), spacings range from 370-1090 mm with a mean of 688 mm. But spacings vary with respect to the paleohillslope, so that to the south (site 3 on Fig. 7) where the Aurora Till Member (and the preserved unoxidized diamicton) is thinner, the spacings range between 100 and 690 mm with a mean of 377 mm.

Joints are opening fractures (Pollard and Aydin, 1988), and their occurrence as a polygonal network indicate formation by shrinkage. The association with oxidized (unsaturated) weathering zones (Hallberg et al., 1978a) suggests the joints formed by desiccation, and this is further supported by the relationship of joint frequency to the landsurface, with decreasing frequency downward and away from the paleolandsurface. Plotted on a Rose diagram, the orientations of the joints forming the polygonal network cluster (Fig. 8). Some data, suggestive of preferred orientations in the joint patterns, may infer that other inherent stress fields influenced the direction of joint opening. However, the resultant patterns and morphology apparent today principally reflect their development during the desiccation and weathering of the deposits. The caution here is that orientation data plotted on Rose diagrams are insufficient to determine the origin of these joints; the 3-dimensional geometry must be characterized and understood in order to make the correct interpretation.

Along the joints are parallel bands of reduced and oxidized diamicton, often a few centimeters wide, that result from episodic water movement down the joints. The width of the bands and the degree of alteration associated with them varies, and indicate different generations of joints. Field relationships indicate that older polygons, with the greatest amount of alteration along them, have successively been broken into smaller polygons by younger joint sets with less alteration. Alteration along the joints varies, depending primarily on age of the joint set and depth. Joint faces may be stained with secondary iron- and manganese-oxides and coated with secondary carbonate.

Through time, quarry operations have exposed different portions of the Late Sangamon paleohillslope. Locally, the Late Sangamon erosion surface descends

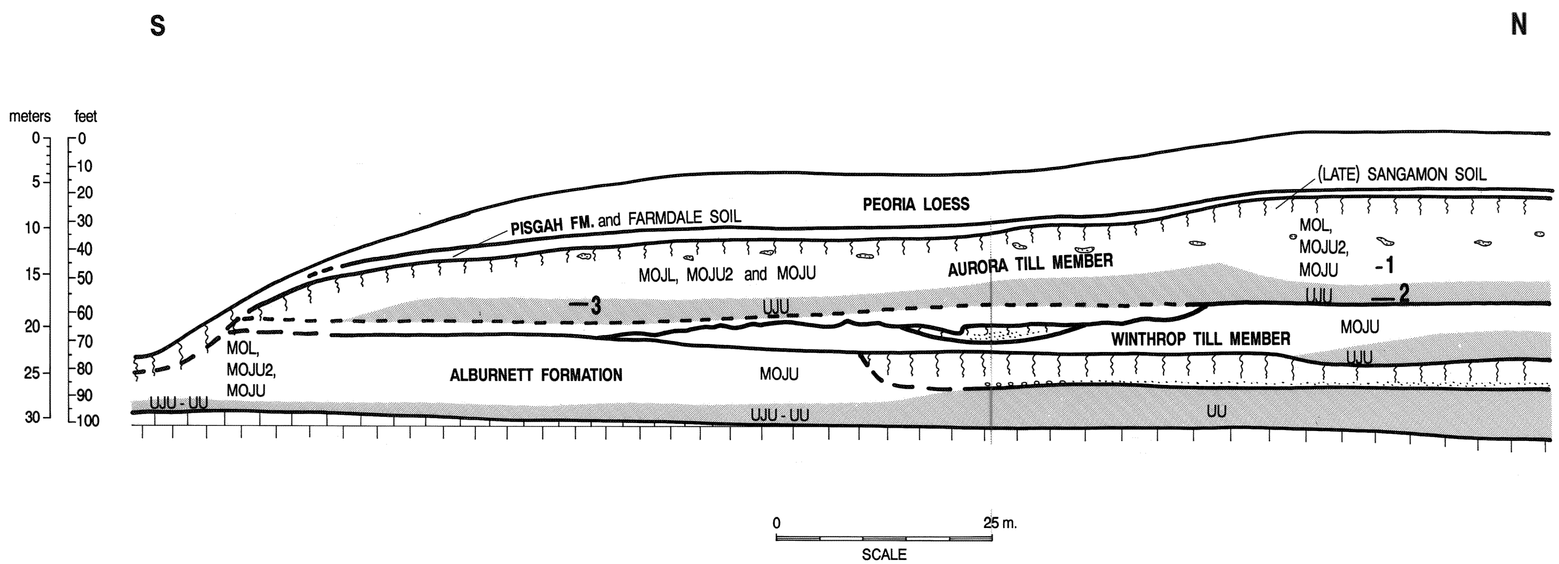



**Figure 7.** Cross-section of the 1991-92 exposure showing locations where vertical joint geometry in the Aurora Till Member was studied in detail (sites 1, 2, and 3).

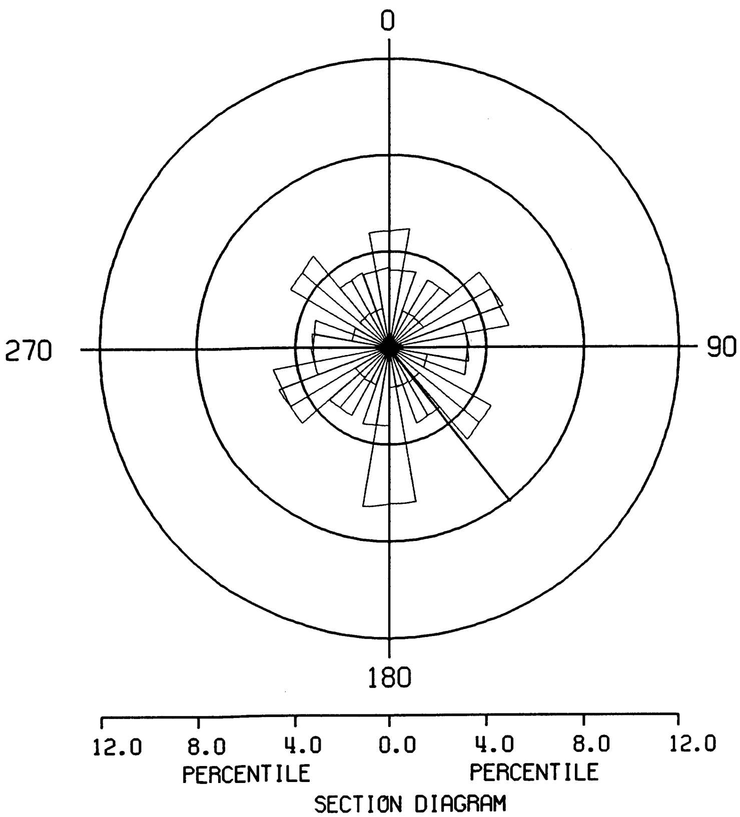



**Figure 8.** Rose diagram of the orientations of vertical joints that form a polygonal network in the Aurora Till Member (site 3 on Fig. 7; 31 joints from 16 contiguous polygons).

to either shallow swales, former drainageways or sidevalleys on the Late Sangamon surface (see also Ruhe et al., 1967). In such positions, the Sangamon Soil thickens into swales and no longer exhibits dark reddish brown colors, but is gleyed, marked by mottled gray and greenish colors indicative of poor soil drainage in these landscape positions. During 1975-76 a large and deep Late Sangamon sidevalley or gully was exposed (see location B on Fig. 2). The gully was nearly 6 m deep and about 3 m wide. A thick cobble lag at the base of the gully was overlain by poorly sorted and crudely stratified deposits grading upward from sandy loam to silty clay loam, clay loam, and clay (Fig. 9). Occasional pebbles and cobbles occurred throughout the deposit. A gleyed, poorly drained, but still strongly developed Sangamon Soil was present in the top of this alluvium, continuous with the better drained Sangamon Soil on the Late Sangamon erosion surface (Fig. 2). There was evidence of multiple soils developed within the alluvial fill, each with A and/or cambic B (Agb/Bgb) horizons (Fig. 9). The soil and stratigraphic sequence of this buried sidevalley are similar to those of low-order drainages on the modern land surface, and illustrate one of the facies that the Sangamon Soil may have.

### *Hickory Hills Till Member*

As discussed in the section on the Aurora Till Member, a thin, complex unit truncated by the Late Sangamon erosion surface overlay the Aurora Till Member in the 1975-76 exposure. The unit contained various sand lenses, and the diamicton was sandier than the underlying diamicton (42% sand vs. 34% in the underlying diamicton), resembling modal sand contents for similarly massive Hickory Hills Till Member diamictons. Some sand bodies had flat upper surfaces overlain by 0.1 to 0.3 m of platy, fissile diamicton [facies Dmm(s)?]. In others, the diffuse bedding in the sands appeared deformed and overturned. Yet other, irregularly shaped sand bodies showed no evidence of deformation. The Sangamon Soil was developed in the top of this unit and the underlying progression of weathering zones was the predictable MOJL/MRJU/MR-UJU sequence. This unit may have represented: 1) a readvance associated with the Aurora Till Member, 2) a supraglacial facies of the Aurora Till Member, or 3) the Hickory Hills Till Member that stratigraphically

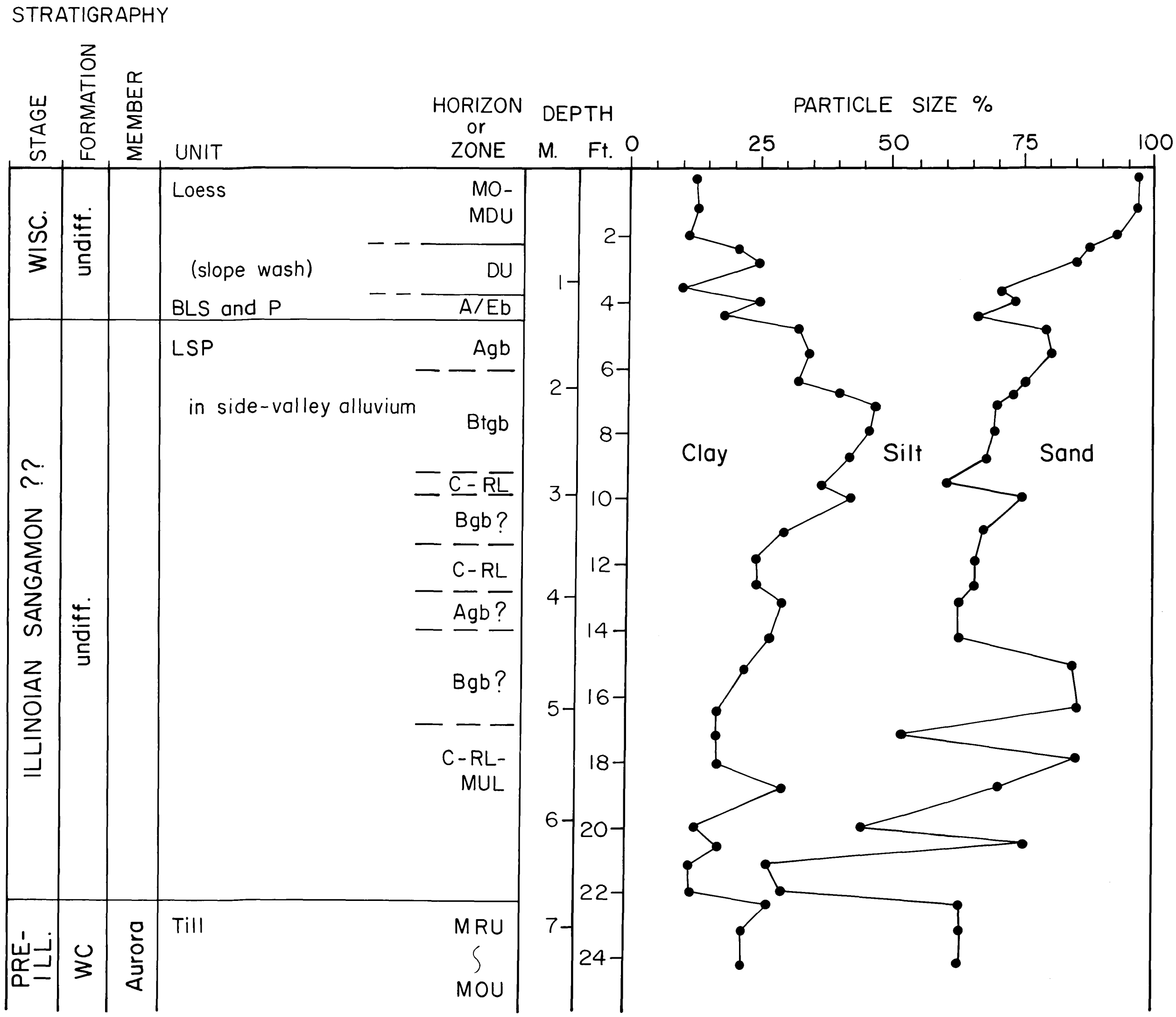



**Figure 9.** Stratigraphy and particle-size data for Late Sangamon sidevalley alluvium exposed in 1983-84 (site B on Fig. 2).

overlies the Aurora Till Member.

It is unlikely that the unit was a supraglacial facies of the Aurora Till Member because no facies indicative of supraglacial resedimentation (e.g., Lawson, 1989) were present. Sedimentary structures as well as density and consolidation data (Table 5) were like basal tills, and textural and carbonate data (where secondary weathering changes had not significantly altered the massive diamicton) were more like properties of the Hickory Hills Till Member (Hallberg et al., 1984). Further, the Hickory Hills Till Member is present in higher elevation primary drainage divides nearby, and weathering zone changes in the unit and in the underlying Aurora Till Member suggested a major break in the stratigraphy. It is most likely that the unit was a remnant of the Hickory Hills Till Member. However, the complications introduced here by erosion surface development and secondary weathering point out how difficult it can sometimes be to make conclusive stratigraphic identifications in these older Quaternary sequences.

## PISGAH FORMATION

The Pisgah Formation, defined by Bettis (1990), is the oldest Wisconsinan unit regionally present in Iowa. Its stratigraphic position is equivalent to the Roxana Silt of Illinois and the Gilman Canyon Formation of Nebraska, but its lithologic properties are different. It is preserved on relatively stable Yarmouth-Sangamon and Late Sangamon surfaces, but is absent on the younger 'Iowan erosion surface' of northeastern Iowa and the geomorphically equivalent 'Iowan' step in the stepped erosion landscapes of other parts of the State (Hallberg et al., 1978c). Previously in Iowa, Pisgah Formation deposits have been referred to informally as a basal soil-stratigraphic unit (e.g., Ruhe, 1976) and as basal loess sediment (e.g., Hallberg, 1980a; Canfield et al., 1984). Within a few kilometers of the Mississippi River, thin sediment lithologically equivalent to the Roxana Silt is present in Iowa, and this formation name will be retained for it there.

***Facies.*** The Pisgah Formation in eastern Iowa is commonly only 0.15 to 1 m thick, although locally thicker sections occur. The unit originated primarily as eolian silt, but usually it has been physically altered by colluvial hillslope processes and/or various pedogenic mixing processes. As a result, Pisgah Formation deposits usually have a "gritty" silt loam texture, with noticeable fragments of coarse sand in the lower few cm. Across most of Iowa, the unit is thin, and it has been pedogenically altered, both at the base, because of slow incorporation into the existing Sangamon Soil, and at the top, from surficial pedogenesis before burial by the Peoria Loess (see below).

At Conklin Quarry, facies of the Pisgah Formation have varied through time as new exposures have revealed different portions of the paleolandscape (Hallberg et al., 1984). The Pisgah Formation presently exposed across the top of the outcrop is about 1 m thick. The basal 10 to 20 cm is pedogenically mixed with the top of the Sangamon Soil developed in 'Late Sangamon pedisediment.' Its upper boundary is the top of a thin, darkened, incipient A horizon (see below) that constitutes the Farmdale Soil. Most of the unit is a gritty, light gray, deoxidized (Hallberg et al., 1978a) silt loam.

***Mineralogy.*** The clay mineralogy of the Pisgah Formation resembles that of the overlying Peoria Loess, with a high percentage of expandable clay minerals, and illite content greater than kaolinite plus chlorite (Table 9). The percentage of expandable clay minerals is slightly higher than that of the Wolf Creek Formation, and Wolf Creek Formation diamictons also have lower percentages of illite relative to kaolinite plus chlorite.

***Secondary Pedogenic and Weathering Properties.*** Pedogenic alteration of the Pisgah Formation varies with thickness of the unit, which is dependent on landscape position as well as distance from an eolian source. The soil developed in Pisgah Formation deposits is the Farmdale Soil or a compound Farmdale/Sangamon Soil.

Where the Pisgah Formation is less than about 0.3 m thick, the deposits are usually pedogenically mixed into the top of the Sangamon Soil. The deposits commonly contain charcoal flecks and differ texturally from the underlying colluvial Late Sangamon 'pedisediment' in that pebbles are absent and the sand content is lower with significantly fewer coarse sand grains. In this setting, a secondary platy/granular soil structure is often weakly developed, which is the upper, E horizon of a compound Farmdale/Sangamon Soil. The platy structure is pedogenic, but may have been affected by post-burial freeze-thaw processes during the Wisconsinan glacial maximum as well (Woida, 1991, 1992; Bettis and Kemmis, 1992).

Where the Pisgah Formation is greater than about 0.3 m thick, pedogenic features vary. Charcoal flecks may be abundant, and the sediment may or may not be darkened from incipient A-horizon development. Commonly, weak platy/granular secondary soil structure has developed. In these settings, the Farmdale Soil is a buried Entisol, in which an A-C or E-C horizon sequence has started to develop. In some cases, a recognizable A-Bw or E-Bw horizon sequence has formed, but this is the exception rather than the rule. In these sequences, the horizonation and weakly developed soil structure indicate incipient soil formation, and the soils are buried Inceptisols. The Farmdale Soil developed in the Pisgah Formation would be considered a first- or lower-order interstadial soil, using the comparative soil-development chart of Follmer (1983), and would be classified as a buried Entisol or Inceptisol (Soil Survey Staff, 1975) depending on the pedogenic properties of individual profiles.

In the present exposure, an incipient A horizon is developed in the upper 10 to 15 cm of the Pisgah Formation. The sediment is darkened (very dark gray), but there has been little development of secondary soil structure. At the base of the deposits, an incipient E horizon developed during initially slow burial of the underlying Sangamon Soil. The preserved horizon

**Table 9.** Laboratory data for the Pisgah Formation and Peoria Loess sampled from the 1975-76 exposure (adapted from Hallberg et al., 1984).

| Depth | Horizon or Zone | Lithofacies | Particle Size - % | | | Clay Mineralogy - % | | |
|---|---|---|---|---|---|---|---|---|
| feet (m) | | | Clay | Silt | Sand | Ex. | Ill. | K + C |
| | PEORIA LOESS | | | | | | | |
| 4.6 (1.4) | OL | Lm | 18.3 | 81.0 | 0.7 | 72 | 17 | 11 |
| 10.2 (3.1) | OL | Lm | 19.9 | 79.6 | 0.5 | 74 | 16 | 10 |
| 15.2 (4.6) | MOU | Lm-Lss | 11.7 | 78.5 | 9.8 | 73 | 16 | 11 |
| 16.4 (5.0) | MO-DU | Lm | 18.3 | 77.6 | 4.1 | 73 | 16 | 11 |
| 17.0 (5.5) | MO-DU | Lm | 18.9 | 80.6 | 0.5 | 68 | 11 | 10 |
| 20.0 (6.1) | MDL (or very weakly calcareous) | Lm | 19.4 | 77.6 | 3.0 | 71 | 19 | 10 |
| | PISGAH FORMATION (BLS) Farmdale Soil (BLP) | | | | | | | |
| 20.7 (6.3) | Eb | L-CmP | 21.4 | 61.5 | 17.1 | 67 | 18 (trace vermiculite) | 15 |

sequence is A-C-Eb.

## PEORIA LOESS

The Peoria Loess in eastern Iowa is part of a regionally extensive loess sheet. It extends across the Midcontinent and mantles Wisconsinan and older surfaces. Most of the Peoria Loess was deposited between about 25,000 and 14,000 years ago in Iowa. Dates at the base are distinctly younger on 'Iowan' erosion surfaces, reflecting the final date these Wisconsinan erosion surfaces stabilized (Hallberg et al., 1978c).

***Facies.*** In many areas, the Peoria Loess is a monotonously thick, massive silt loam, but thickness and texture vary with distance from, and orientation with respect to the source(s) (e.g., Smith, 1942; Ruhe, 1969; Handy, 1976; Lutenegger, 1979). In the Iowa City area, the Iowa River valley was a local loess source, and thicknesses and textures vary. At Conklin Quarry, however, the Peoria Loess has been a uniformly massive silt loam. The maximum thickness on the Late Sangamon interfluve at the present exposure is about 7 m, but the loess becomes progressively truncated down the sideslopes.

***Mineralogy.*** The clay mineralogy of the Peoria Loess has a high percentage of expandable clay minerals, and illite content is higher than kaolinite plus chlorite (Table 9).

***Secondary Pedogenic and Weathering Properties.*** The modern soils developed across most of Conklin Quarry have been Alfisols (Fayette Series), forest soils with A-E-Bt-C horizon sequences (Schermerhorn, 1983). At present, the 'modern soil' has been partially truncated by quarry operations and buried by fill (Fig. 3).

Beneath the modern solum a typical weathering zone sequence more or less parallel to the modern landsurface has developed: OL (oxidized and leached), OL2 (oxidized, leached, but with secondary carbonates), OU (oxidized and unleached), MOU (mottled oxidized and unleached), DU (deoxidized and unleached), and DL2 (deoxidized, leached, but with secondary carbonates). Secondary carbonates in the OL2 zone are precipitated from carbonate leached from the overlying soil and OL weathering zone. The secondary carbonates form small, hard, irregularly shaped concretions (in the past, these have sometimes been referred to in the loess literature as *loess kindchen,* German for 'little children' or 'dolls', which they can be imagined to be). Small shells of terrestrial snails are preserved throughout the calcareous portions of the Peoria Loess at this site. At the boundary between the oxidized and deoxidized weathering zones, is a 10 cm thick zone of secondary iron- and manganese-oxide accumulation. The iron and manganese oxides are derived from weathering in the overlying horizons. They have been precipitated where geochemical conditions change at the top of the deoxidized zone. The light gray loess is called 'deoxidized' because the matrix has virtually no free iron left in it (Hallberg et al., 1978a). The deoxidized zone is a zone where water tables fluctuate, the underlying Sangamon Soil perching water during periods of high precipitation (Hallberg et al., 1978a). When the water table is high, the loess is saturated and the free iron is in a highly mobile, reduced state. As the water table fluctuates, this iron moves and precipitates when the water table drops and the loess begins to dry out, and the remaining water becomes supersaturated with respect to iron. The iron preferentially precipitates in larger voids, such as former root channels, through which water movement is concentrated. The deoxidized loess at Conklin Quarry has abundant hard, tubular 'pipestems', secondary iron-oxide concretions formed along former root channels that are reprecipitated from iron originally in the deoxidized loess matrix.

## WISCONSINAN EROSION SURFACES

Wisconsinan erosion surfaces are not well exposed at present and will not be seen on the trip, but important stratigraphic, geomorphic, and paleoenvironmental information has been gained from them. Subaerial erosion surfaces have episodically entrenched the pre-Illinoian glacial sequence (see accompanying sidebar on pp. 34-35). The regionally developed Late Sangamon erosion surface has been discussed previously in the section on the Aurora Till Member. On sloping portions of the Late Sangamon erosion surface at Conklin Quarry small gullies have locally truncated the Sangamon Soil (Fig. 2, sites C and D). These gullies are filled with thicker increments of Pisgah Formation deposits (primarily colluvial facies) and there is an abrupt discontinuity between the Pisgah Formation deposits (BLS and BLP on Fig. 10) and the truncated B horizon in the Sangamon Soil (LSPs and LSP on Fig. 10).

Stratified slope wash deposits at the base of the Peoria Loess, but overlying the Farmdale Soil/Pisgah Formation deposits, often overlie these Wisconsinan gullies. This is the stratigraphic setting of the Conklin Quarry Local Biota, a fossil assemblage that indicates tundra conditions in this part of Iowa during the Wisconsinan glacial maximum (see below).

Later Wisconsinan 'Iowan' erosion surfaces have also been exposed in the quarry in the past (Fig. 2, site E). The pediment marking the Iowan erosion surface is inset below and truncates the Pisgah Formation and Farmdale Soil (BLS and BLP on Fig. 2), the Late Sangamon erosion surface, and the Sangamon Soil (LSPs and LSP on Fig. 2). The eroded pre-Illinoian diamicton is directly overlain by calcareous slope wash and Peoria Loess (Figs. 2 and 11). The base of the Peoria Loess in this geomorphic setting typically dates about 17,000 RCYBP (Hallberg et al., 1978c).

***Paleoenvironmental Interpretation from Fossil Biota.*** The Conklin Quarry Local Biota is a diverse fossil assemblage of pollen, plant fragments, insect and vertebrate remains, and mollusc shells that were subject of an intensive collaborative research effort by Baker et al. (1986). The assemblage was preserved in a small swale incised into the Pisgah Formation and the underlying Aurora Till Member in the upper reaches of a first-order drainageway. The swale was about 3 m wide and 0.6 m deep. Although the swale was filled predominantly with alluvial silt, extensive excavation in 1984 revealed a thin, poorly stratified basal lag of sand and small pebbles. Lobes of sediment derived from the Sangamon Soil, resembling solifluction lobes, had flowed from the paleogully sides and were intercalated in the lower half of the fill (R.S. Rhodes, II, personal communication). Fossil-rich alluvial silt deposition ceased when Peoria Loess deposition overwhelmed the drainageway and mantled the landscape. The base of the fill was radiocarbon dated at 18,090$\pm$190 B.P. (Beta-12527), the middle at 17,170$\pm$205 (DIC-1240), and the top at 16,710$\pm$270 (Beta-12528).

The biota consist of a mixture of tundra, boreal forest, and wide-ranging species. These all inhabited microenvironments that could have existed at or near the swale: silt-bottomed aquatic environments, calcareous sandy to clayey pond or stream margins, rich fens (wetlands) underlain by peat, and well drained sandy or gravelly uplands.

The pollen record was sparse, dominated by *Picea* (spruce), *Pinus* (pine), and Cyperaceae (sedge), and pollen accumulation rates were low. The plant macrofossils included a number of tundra species, such as *Silene acaulis* (moss campion), along with *Betula glandulosa* (dwarf birch), *Picea* (spruce) and *Larix* (larch) needles, and small pieces of wood. The general reconstruction based on plant remains was a site near treeline; the combination of tundra and boreal plants suggested a variety of habitats in an open landscape where stunted spruce and larch trees were scattered. The insect fauna also contained a mix of tundra, boreal forest, and wide-ranging species. Without exception, all elements in the insect fauna could occur today within or near the forest/tundra transition zone. Small mammals included the tundra indicators *Dicrostonyx* (collared lemming), and probably *Microtus miurus* (singing vole) together with boreal forest taxa. The molluscs included extinct and relict species and showed the widest range in present geographic distribution, but Rocky Mountain and especially northern elements predominated. Paleoenvironmental reconstruction based on comparison between the fossil and modern biota indicates that the climate was probably colder (11-13$^{o}$ colder July temperatures) and more moist than in Iowa today, and that it rather closely resembled the climate at the modern tree limit in northern Canada.

## SUMMARY

Our walk through the stratigraphy of Conklin Quarry has pointed out the complexities of loess-mantled pre-Illinoian glacial sequences in the Midcontinent. A wide variety of facies are preserved from the multiple glacial, fluvial, eolian, and colluvial (hillslope) environments that have occurred during the last 1-2 million years. Yet, interpretation of this record is difficult. Glacial and subaerial unconformities occur throughout the sequence; complete preservation of units is rare, and stratigraphic differentiation can only be made by thorough characterization and extensive regional study. All of the units have been pedogenically altered, and this alteration can hinder or prevent facies interpretations, depending on the magnitude of alteration that has taken place. Since the end of pre-Illinoian glaciation, an integrated drainage network has episodically developed across virtually the entire landscape. As this drainage network evolved, primary glacial landforms have been destroyed. Beneath different erosion surfaces (Late Sangamon, Iowan, and Holocene) entire stratigraphic units (till members) have often been truncated; for example, each of the formations and till members present in the Conklin Quarry sequence have locally been exhumed and are the surficial unit in different locations on the Iowan erosion surface of eastern Iowa (Hallberg, 1980a). Study of the Conklin Quarry exposures gives a perspective on these complications, and provides a background of the stratigraphic, sedimentologic, pedogenic, and geomorphic concepts that must be used to unravel this complicated record of Quaternary time.

## ACKNOWLEDGEMENTS

Research at Conklin Quarry has been possible because of the assistance and cooperation of the River Products Company, Inc. We wish to thank General Manager Tom Scott, in particular, for the support and encouragement he has given through the years.

R.S. Rhodes, II, and R.G. Baker provided helpful reviews of the manuscript.

Many laboratory personnel have untiringly provided analyses through the years: Christie York, John Littke, Deb Quade, Catherine Goodman Sammis, Neil Walter, Terry Etzel, Sue Lenker, Tim Tvrdik, and John Coughlin.

We would like to thank Mary Pat Heitman for typing the tables, and Patricia Lohmann and Kay Irelan for their skillful work on the illustrations. Pat Lohmann did the professional layout that makes this publication so pleasing to look at and easy to use.

## REGIONAL SETTING

Conklin Quarry is located in the Southern Iowa Drift Plain near its northern border with the Iowan (erosion) Surface (Prior, 1991). The Southern Iowa Drift Plain was glaciated several times prior to the Illinoian Episode during the interval from before 2.2 million to 500 thousand years before present (Hallberg, 1986). Quaternary deposits in this area discontinuously cover an irregular bedrock surface. Since the end of pre-Illinoian glaciations, an integrated drainage network has developed from episodic erosion of the landscape. Two Wisconsinan loess sheets mantle the landscape; these are differentially preserved as a result of late Wisconsinan and Holocene erosion.

The Quaternary record of the Southern Iowa Drift Plain is fragmentary because of multiple periods of both glacial and subaerial erosion. No primary glacial landforms remain, although scattered loess-mantled tabular divides underlain by 'Yarmouth-Sangamon' paleosols are considered to be possible remnants of the youngest pre-Illinoian drift plain (e.g., Kay and Apfel, 1929; Ruhe, 1969). The present landscape is thus dominated by stream dissection and erosional landforms. Across the Southern Iowa Drift Plain, at least four different *sets* of surfaces can be identified: the Yarmouth-Sangamon, Late-Sangamon, Iowan and Holocene surfaces.

In eastern Iowa, the loess-mantled Yarmouth-Sangamon surface is preserved only on narrow, nearly flat upland divides. This surface is perhaps the remnant of the youngest pre-Illinoian drift plain which was subject to weathering and local modification until burial by Wisconsinan loesses. Generally, a thick gray (poorly drained) soil (now buried) is developed on the Yarmouth-Sangamon surface. This soil was named the Yarmouth-Sangamon Paleosol (Ruhe et al., 1967) because it was presumed to transgress Yarmouth and Sangamon time. Unfortunately, like many other paleosols, it was named in the context of time terms rather than independently, as recommended by the present stratigraphic code (NACSN, 1983). In strict terms, the 'Yarmouth-Sangamon Paleosol' is a facies of the Sangamon Soil (Geosol) because the units which bury and stratigraphically define them are equivalent.

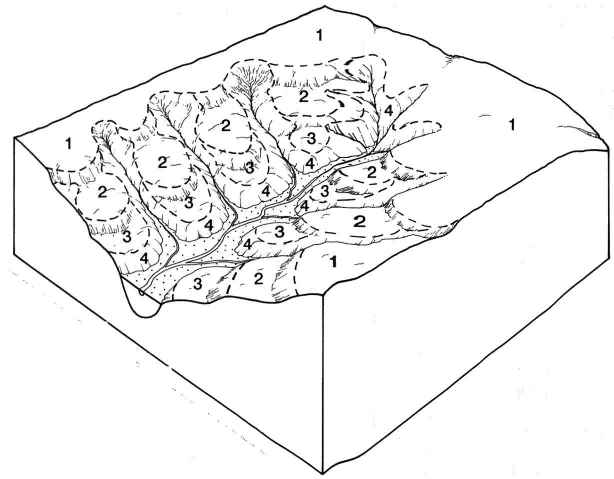
The Late-Sangamon surface is a set of erosion surfaces cut into and inset below the Yarmouth-Sangamon surface of the primary divides. The break between the Yarmouth-Sangamon and Late-Sangamon surfaces is marked by topographic, geomorphic, and pedologic discontinuities (Ruhe et al., 1967; Hallberg et al., 1978c). In eastern Iowa, the Late-Sangamon surfaces generally consist of gently sloping loess-mantled pediments that are now only partially preserved as steps (levels) at about the same elevation on interfluves. In localized areas, other parts of the Late-Sangamon landscape, from the pediments to the valley-slope fans to the floodplain, are preserved. After, and in part during, the later stages of cutting of the Late-Sangamon erosion surfaces, soil formation occurred, indicating a change to relatively more stable hillslope conditions. This soil developed until burial by Wisconsinan loesses, and has been called the Late-Sangamon Paleosol in Iowa (e.g., Ruhe et al., 1967; Hallberg et al., 1978c). Compared to the Yarmouth-Sangamon paleosols, Late-Sangamon paleosols are generally less weathered, have thinner sola, and are better drained with generally red to reddish-brown colors (Ruhe, 1969; Hallberg et al., 1978c, 1980b). Late Sangamon paleosols are typically developed in multiple parent materials: 1) an upper unit of "pedisediment," sediment derived from upslope erosionof the pediment; 2) a stone line or gravel lag which marks the pediment/erosion surface; and 3) underlying glacial deposits (Canfield et al., 1984; Ruhe et al., 1967; Ruhe, 1969). Pedogenesis commonly continued during slow burial by Wisconsinan-age Pisgah Formation deposits, resulting in upbuilding of the Late-Sangamon Paleosol. In strict terms, the Late-Sangamon Paleosol is also a facies of the Sangamon Soil because the stratigraphic units which bury and define it are the same as those in the type area of the Sangamon Soil.

Another set of erosion surfaces, called the Iowan Surface, are inset below the Late-Sangamon surfaces in the Southern Iowa Drift Plain. This set of erosion surfaces have been referred to by various terms in previous literature: the "Iowan surface" (Ruhe et al., 1968; Prior, 1991), the "Iowan Erosion Surface" (Ruhe, 1969;

Hallberg et al., 1978c), and the "Early Wisconsin pediment" (Ruhe et al., 1967). The break between the Late-Sangamon and Iowan surfaces is again marked by topographic, geomorphic, and pedologic discontinuities. In eastern Iowa, the Iowan surface consists of gently sloping, loess-mantled pediments which are generally shorter in length than the Late-Sangamon pediments. Again, only remnants of these pediments are preserved, and they occur as steps or levels down interfluves below Yarmouth-Sangamon and Late-Sangamon surfaces and above Holocene surfaces. The Iowan surface represents a renewed period of relatively rapid downcutting, and it is again marked by a stone line or gravel lag that is commonly overlain by a thin increment of colluvium formed as the erosion surface developed upslope. The Iowan erosion surfaces were cut just prior to and during the Wisconsinan glacial maximum. Regional deposition of the Peoria Loess occurred during development of the surfaces: Peoria Loess is thinner on Iowan surfaces than on Yarmouth-Sangamon and Late-Sangamon surfaces upslope, and basal radiocarbon ages are younger (Hallberg et al., 1978c; Ruhe et al., 1968). Early increments of Peoria Loess accumulated on the relatively "stable" Yarmouth-Sangamon and Late-Sangamon surfaces, but did not accumulate where the Iowan erosion surface was actively being developed. During the later phases of Peoria Loess deposition, the Iowan surfaces stabilized and the last increments of loess were deposited on them. No buried soil is present on this surface because it was immediately buried by Peoria Loess.

A final period of downcutting and headward extension of the drainage system has occurred during the Holocene. Holocene erosion surfaces are present on portions of upland slopes and in the upper part of the drainage network as a result of headward stream extension. The Holocene alluvial valleys consist of a series of multiple, often subtle terrace surfaces. These terraces and associated deposits can be grouped into various members of the DeForest Formation (Bettis, 1990; in prep.).

In different parts of the Southern Iowa Drift Plain various surfaces dominate the landscape because of differential preservation (Hallberg et al., 1980b; 1978c; Ruhe, 1969). In much of east-central and southern Iowa, the loess-mantled Late-Sangamon surface is best preserved. Conklin Quarry has exposed several cross-sections of a Late-Sangamon interfluve. Because such exposures are uncommon, the Conklin Quarry exposures present an excellent opportunity to study this ancient landscape.




LEGEND

1 Loess-mantled Yarmouth-Sangamon surface and paleosol

2 Loess-mantled Late Sangamon erosion surface and paleosol

3 Loess-mantled Wisconsinan age ("Iowan") erosion surface

4 Location of major Holocene age erosion

Location of major Holocene age deposition

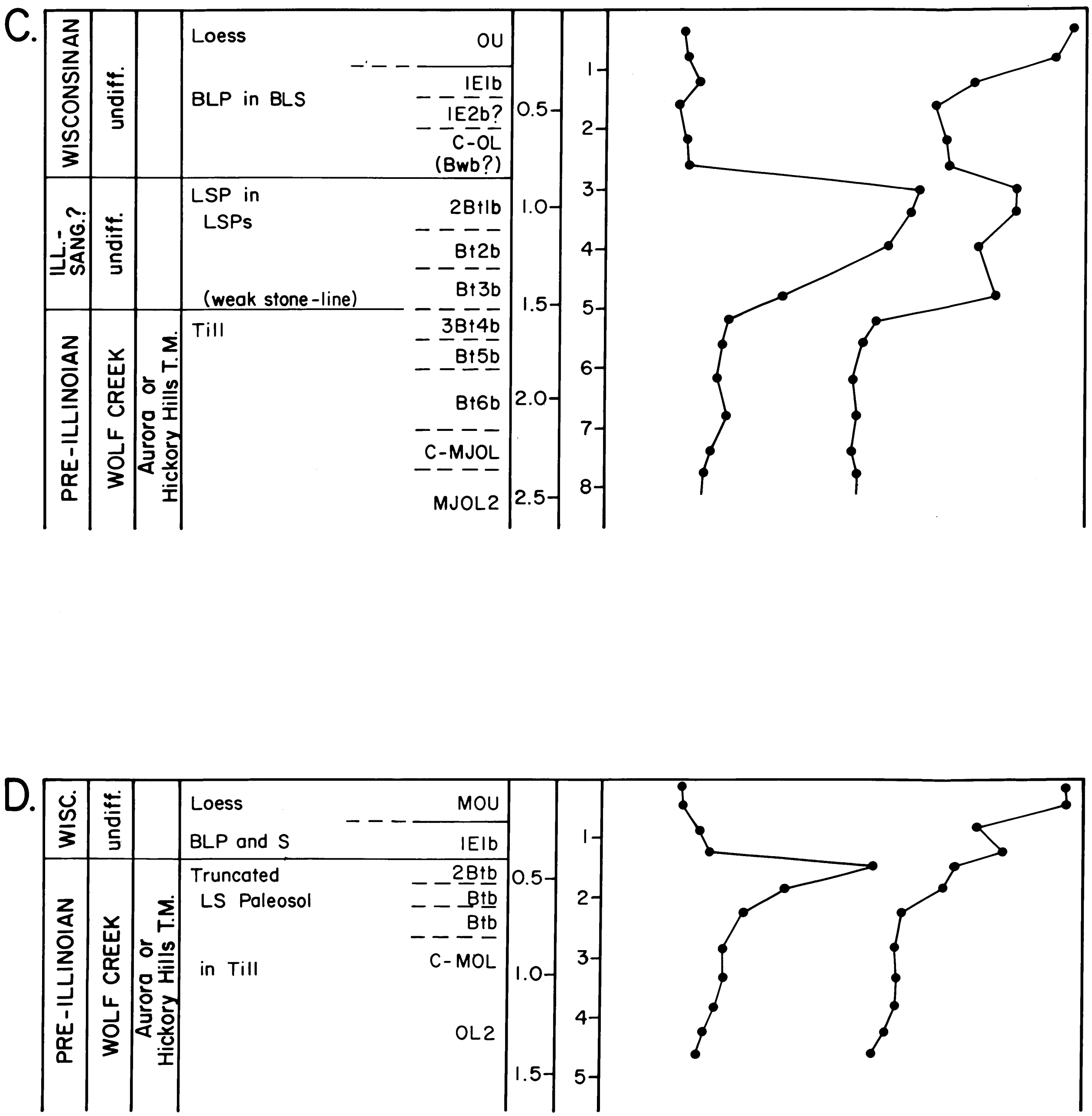



**Figure 10.** Stratigraphy and particle-size distribution of Wisconsinan-age gully fills on the Late Sangamon erosion surface (sites C and D on Fig. 2).

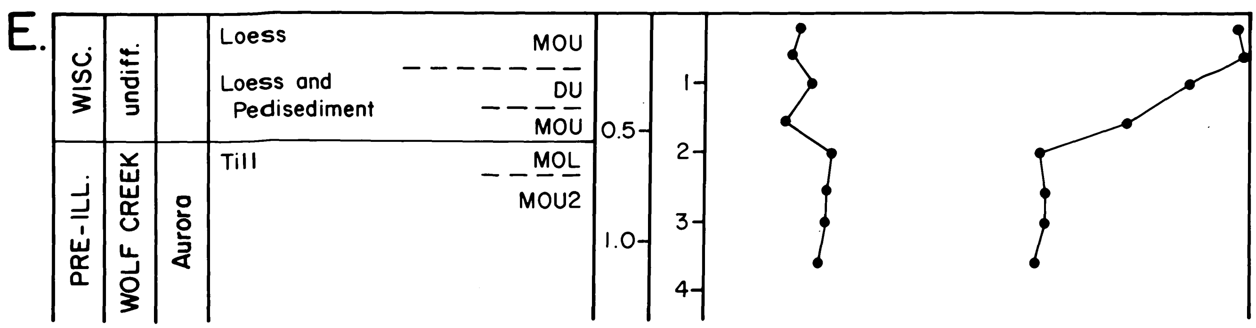



**Figure 11.** Stratigraphy and particle-size data for a profile of the Wisconsinan-age 'Iowan' erosion surface of the 1983-84 exposure (site E on Fig. 2).

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**Iowa Department of Natural Resources**
Energy and Geological Resources Division
Geological Survey Bureau
109 Trowbridge Hall
Iowa City, Iowa 52242-1319
(319) 335-1575