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A Unique Exposure of Quaternary Deposits in Johnson County, Iowa

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The Klein Quarry, in Johnson County, Iowa, exposes a unique section of Quaternary deposits. The section extends along the axis of a Late-Sangamon erosion surface. It is mantled by Wisconsinan loess: a 4-5m upper increment of Late-Wisconsinan loess and a thin increment (0.2 to 0.5m) of mixed loess and Wisconsinan-age pedisediment ('basal-loess sediments'). Some soil development has taken place in the basal-loess sediments (basal-loess paleosol), and this soil merges with the underlying Late-Sangamon Paleosol. The Late-Sangamon erosion surface is developed on Pre-Illinoian age deposits of the Wolf Creek Formation which include (from top to bottom) an upper basal till (the Aurora Till Member), a thin, laminated diamicton, and an underlying stratified fluvial sequence of sand, silt, and gravel. These overlie till of the Alburnett Formation which is locally preserved in low-relief sags on the underlying bedrock surface of Devonian Cedar Valley Limestone. Sedimentary structures, pebble fabrics, and stratigraphic relations suggest that: the stratified fluvial sequence originated as a proglacial fluvial outwash that evolved into a low-energy slackwater environment; the laminated diamicton was derived from glacial sediments which were resedimented and deposited in this slackwater environment; and this was followed by overriding of glacial ice and deposition of the basal till.

The Late-Sangamon erosion surface is marked by a stone line and a relatively thin increment of associated pedisediment which overlies the stone line. Various hillslope components are exposed going down the Late-Sangamon paleohillslope. The erosion surface progressively truncates the Aurora Till Member, the laminated diamicton, and most of the stratified sequence of the Wolf Creek Formation. Properties of the stone line and pedisediment vary in a complex, but systematic way. The characteristics of the stone line and lowermost pedisediment vary downslope directly with textural variations in the different deposits underlying the erosion surface. The uppermost pedisediment, however, shows little relationship to the materials underlying the stone line. The upper, younger pedisediment has resulted from reworking older pedisediment and from transport of sediment from farther upslope. The greater transport distance and reworking results in greater sorting and a less direct relationship to local source materials.

The Late-Sangamon Paleosol formed on this paleohillslope, and is developed in the Late-Sangamon pedisediment, stone line, and the underlying Wolf Creek Formation deposits. Sedimentological variations in the pedisediment affect various paleosol properties. Thickness of the paleosol varies (1.8 to 2.3m) directly with the thickness of pedisediment, becoming thicker down the paleoslope. The increase in paleosol thickness is also directly matched by an increase in B-horizon thickness. The pedologic and sedimentologic features indicate that the Late-Sangamon erosion surface — pedisediment — paleosol evolved slowly and systematically. Pedisediment must have accumulated in the lower-slope positions at a slow enough rate that B-horizon soil development kept pace with sediment accumulation.

INDEX DESCRIPTORS: Quaternary, glacial deposits, till, diamicton, erosion surface, pedisediment, paleosols, soil geomorphology.

Klein Quarry (currently operated by River Products Company, Iowa City) is located about 4.5 km west of Iowa City (T. 79 N., R. 7 W., NE ¼, sec. 2) in Johnson County, Iowa. In the southeastern part of the quarry a 180 m long section of Quaternary deposits has been exposed overlying Devonian limestones. The Quaternary sequence exposed in the section is particularly interesting and significant. First, deposits are exposed which differ in age and origin, including Wisconsinan-age loess (eolian silts), a 'Late-Sangamon age' erosion surface, stone line, and associated pedisediment and a sequence of Pre-Illinoian age tills, glaciofluvial, and glaciolacustrine deposits. Second, the section is aligned along the length of an interfluve, exposing an axial section of the loess-mantled, Late-Sangamon pediment and paleosol (buried soil). As such, the exposure is an excellent site to study the nature and lateral variation of the Late-Sangamon paleosurface.

Regional Setting

The upland Quaternary stratigraphy in the Johnson County area is generally comprised of 5 to 10m of Wisconsinan-age loess overlying a variable thickness of Pre-Illinoian age glacial deposits (Hallberg, 1980a, b, Hallberg et al., 1978a). The loess is thickest near the Iowa River valley which was a local source of the loess (Hallberg et al., 1978a; Lutenegger, 1979). At the base of the loess occurs a thin unit, which in Iowa is informally referred to as "basal-loess sediment," a mixture of loess and sediment derived locally from hillslope erosion (Hallberg et al., 1980a). A weakly developed soil was formed in this unit and is informally referred to as the "basal-loess paleosol" (Hallberg et al., 1978a, 1980a, b; Ruhe, 1969). In this area the basal-loess paleosol has been radiocarbon dated at 22,000 to 25,000 RCYBP (radiocarbon years before present; Hallberg et al., 1978a).

The Pre-Illinoian deposits have been formally classified into the Alburnett Formation and the younger Wolf Creek Formation (Hallberg, 1980a). Both formations consist predominantly of glacial till, but include other types of deposits as well. The formations (and their members) are differentiated by various physical and mineralogical characteristics (Hallberg, 1980a).

The landscape in this region has been evolving since the end of these Pre-Illinoian glaciations. The area is well dissected, and the landscape within the drainage basins is comprised of a consistent set of multi-leveled, stepped erosion surfaces which differ in age (Ruhe, 1969; Hallberg et al., 1978a). They indicate that the erosional development of this landscape was episodic, with periods of relatively rapid downcutting followed by periods of relative stability, rather than continuous, uniform erosion since the last Pre-Illinoian glacia-

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tion. There are four sets of surfaces descending from the divide to the valley floor (where parts of all of the surfaces have been preserved): the Yarmouth-Sangamon surface, the Late-Sangamon erosion surfaces, the Wisconsinan or "Iowan" erosion surfaces, and the alluvial valley floor (Hallberg et al., 1978a; Ruhe, 1969). In different areas of the state different surfaces may dominate the landscape (Hallberg et al., 1980a, b; 1978a; Ruhe, 1969). In much of east-central and southern Iowa the loess-mantled Late-Sangamon surface is dominant.

The Klein Quarry exposure reveals a cross section along the axis of an interfluve on the Late-Sangamon pediment. Such exposures are not only rare, but generally short-lived. Thus, the Klein Quarry exposure offers an unusual opportunity to see and study a segment of this ancient landscape. Also, the quarry operation may keep this exposure accessible for future study and research. This paper will describe various aspects of the stratigraphy, sedimentology, and soil development on this paleohillslope.

Procedures

The Quaternary deposits were described using standard textural classes (Walter et al., 1978) and standard weathering zone terminology (Hallberg et al., 1978b). Buried soils were described using standard pedologic terminology and horizon nomenclature (see Soil Survey Staff, 1951, 1975). New soil horizon symbols which are being instituted by the U.S.D.A.-Soil Conservation Service (Guthrie and Witty, 1982) are given in parentheses in the paleosol descriptions and discussion. Laboratory methods used for particle-size analysis are described in Walter et al., 1978, and the procedure for determination of clay mineralogy is given in Hallberg et al., 1978c. (In this paper sand particle-size is considered as < 2mm, $> 62\mu$m; clay as $< 2\mu$m.)

Pebble fabrics in the till and diamicton were measured in the field on gravel-size clasts (generally medium to very fine pebbles) that were approximately prolate in shape. Only this restricted fabric was measured because: 1) it is (relatively) quick and simple to measure pebble-size clasts in the field; and 2) while pebble shape can influence pebble orientation, prolate-shaped particles have been shown useful in determining whether or not there has been orientation related to an active glacial stress system (Holmes, 1941; Boulton, 1971; Drake, 1974; Lawson, 1979; among others). Measurements of the pebble orientations (azimuth trend and plunge or dip) were plotted on Schmidt equal-area stereo nets (lower hemisphere projection) by computer and contoured according to the method of Kamb (1959) at a contour interval of 2 σ. The fabric data was evaluated statistically by the eigenvalue method of Mark (1973; see acknowledgements also). The pebble fabrics were measured over 40 cm by 40 cm areas on the exposure face. The fabrics were measured in zone 0.6 to 1.0m above the base of the massive Wolf Creek Formation basal till.

For the description and measurement of the site, a horizontal base line 165 m long was chained and staked. Relative elevations were determined by leveling. The stratigraphy was measured at least at every 15m increment along the base line. Detailed soil descriptions were made at pertinent locations. A cross section of the exposure was constructed in the field by sketching in the stratigraphy between the measured sections (Figure 1). The section was sampled for laboratory analyses at four stations.

STRATIGRAPHY

Figure 1 is a cross section showing the stratigraphy of the site. The upper surface of the Wisconsinan loess has been disturbed by quarry operations and in places is mixed with spoil. Thus, the loess thickness could not be measured exactly, but is approximately 4.5-5.0m. All detailed section descriptions (Appendix) begin somewhere within the lower portion of the loess. The Late-Sangamon erosion surface progressively truncates the Pre-Illinoian deposits to the north (figure 1). Thus, the most complete stratigraphic section occurs at the south end of the section. The stratigraphy near the south end of the section, at the 10m station, may be summarized as: 0 to about 5.0 m — Wisconsinan loess; 5.0-5.2m — "basal-loess" sediments and "basal-loess" paleosol; 5.2-5.7m — Late-Sangamon pedisediment (and Paleosol); 5.7-5.8m — stone line; 5.8-7.7m — Wolf Creek Formation till (with Late-Sangamon Paleosol in upper portion); 7.7-7.9m

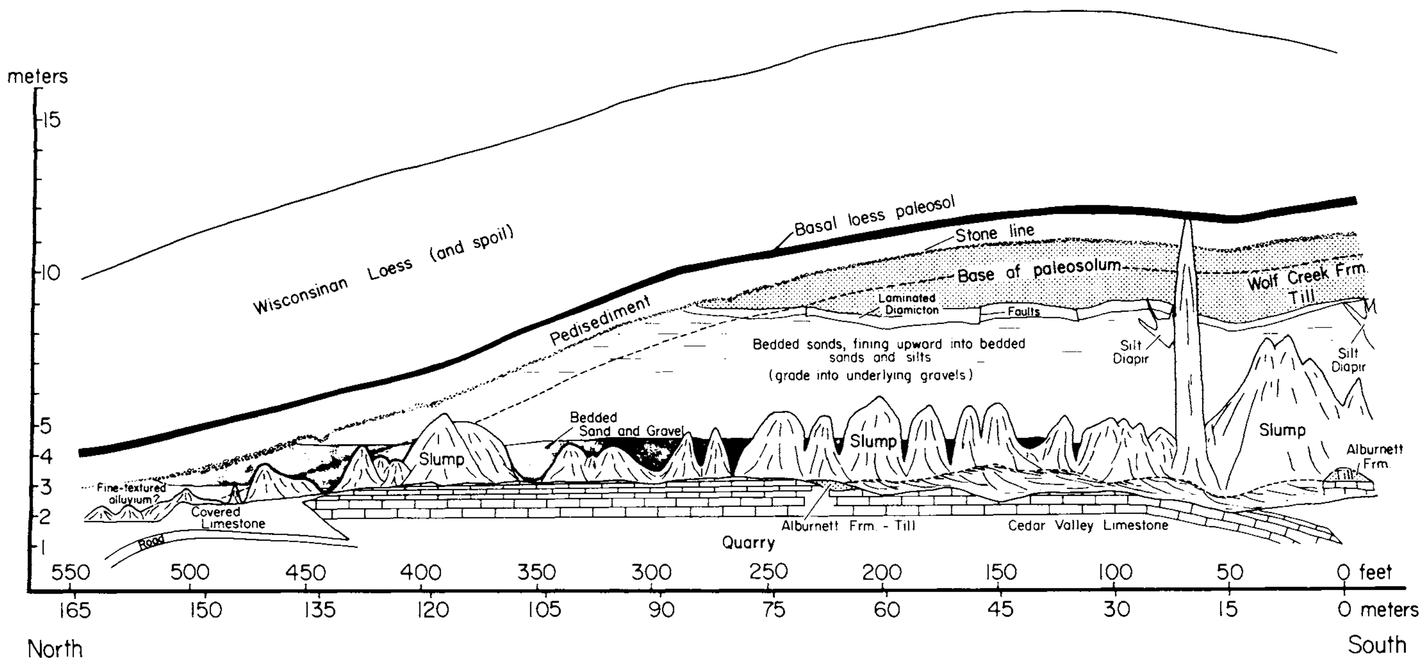

Fig. 1. Measured cross section of the Klein Quarry exposure. Note that Late-Sangamon erosion surface (marked by stone line) truncates various stratigraphic units. Base of Late-Sangamon Paleosol marked by dashed line. Vertical exaggeration 3x.

Table 1. Clay mineralogy at 10 m section, Klein Quarry.

Depth m	Zone	Ex.[a]	Ill.[a]	K+C.[a]
	WOLF CREEK FORMATION			
	Aurora Till Member			
2.6	MRJL	68	13	19
2.7	MR-OJL	68	14	18
2.9	MRJL	66	13	21
3.0	MRJL2	70	14	16
	Laminated diamicton			
3.2	MOL2	68	12	20
	"Till" ball in sands			
3.8	MOL	64	14	22
	Silty clay loam within sands			
4.4	MRL	55	10	35
	Silty diapir within sands			
4.6	MRL	64	15	21
	ALBURNETT FORMATION			
	Undifferentiated till			
8.3	UU	48	22	30
8.5	UU	44	25	31
8.7	UU	45	25	30
8.8	UU	40	26	34[b]
9.0	UU	44	24	32
9.2	UU	40	24	36[b]

[a]% expandable clays, illite, kaolinite plus chlorite.
[b] trace vermiculite

— laminated diamicton; 7.9-12.8m — Wolf Creek Formation fluvial sands and gravel; 12.8-13.8m — Alburnett Formation till; below 13.8 m — Devonian age, Cedar Valley Limestone. The stratigraphy and particle-size data at the 10m station, are shown schematically in figure 2, and the detailed description of the section is in the Appendix (Description 1). The clay mineralogy for this section is given in Table 1.

Wisconsinan Loess

The loess was neither described nor sampled in detail for this study, but there are several studies available documenting regional loess properties (see Ruhe, 1969; Lutenegger, 1979). In Iowa the Wisconsinan loess consisrs of two persistent rock-units, which have not yet been formally defined.

At the Klein Quarry section, these loess units consist of a thick upper increment approximately 4 to 5m thick, and a lower increment 0.2 to 0.5m thick. In previous literature, the upper increment has been referred to as "upper Wisconsin loess" (Ruhe, 1976) or simply Wisconsin or Wisconsinan loess (Hallberg et al., 1980a). This rock unit is essentially equivalent to the Peoria Loess, defined in Illinois as a formation (Willman and Frye, 1970). In Iowa, the thinner lower increment has also been called a variety of names such as "lower Wisconsin loess" (Ruhe, 1976) and the "basal-loess sediments" (Hallberg et al., 1980a). Deposits in a similar srratigraphic position in Illinois have formally been defined as Roxana Silt or Robein Silt (Willman and Frye, 1970). Radiocarbon ages for these deposits in Iowa do not always fall into the ages assigned to these deposits in Illinois, and the Iowa deposits are notably time transgressive (Ruhe, 1976).

At the Klein Quarry the modern surface soil is developed in the top of the loess. In this area, modern sola developed in the loess are generally 1.2 to 1.5m thick. The loess at this section is a uniform silt loam and is oxidized and leached of carbonate throughout.

At the base of the loess is a thin (0.2-0.5m) increment of "basal-loess sediments." These sediments are about 20% higher in sand content than the overlying loess (figure 2). The "basal-loess paleosol" developed in these thin sediments when they comprised the former land surface, producing an A2 (E) soil horizon which merges with, but is clearly separable from, the subjacent Late-Sangamon Paleosol. Section descriptions in Appendix 1 detail typcial properties of the basal-loess sediments and paleosol. The basal-loess sediments are distinguishable from the overlying late Wisconsinan loess by differences in texture and by the weak to moderate platy soil structure (as compared to the more massive structure of the overlying loess), and by various secondary pedogenic accumulations such as flecks of organic matter and secondary accumulations of iron and manganese oxides which prominently mottle the basal-loess sediments.

Wolf Creek Formation

Stratigraphically underlying the loess at Klein Quarry are three units of the Pre-Illinoian age Wolf Creek Formation: an upper unit of uniform diamicton, which we interpret as basal till, which is up to 2m thick; a thin (0.3 to 0.5m thick) middle unit of laminated diamicton; and a lower unit of stratified sand, silt, and gravel, which is up to 5m thick (Figures 1 and 2). The clay mineralogy of all three of these units is dominated by high percentages of expandable clay minerals (Table 1) typical of the Wolf Creek Formation regionally (Hallberg, 1980a, b; Hallberg et al., 1980b). In the exposed section, the three units are progressively truncated to the north by the Late-Sangamon pediment (Figure 1). The erosion surface marking this truncation is denoted by a stone line. Overlying the stone line are thin, reworked hillslope sediments or 'pedisediment' which thicken toward the Late-Sangamon footslope (Figure 1). The Late-Sangamon Paleosol is developed in the pedisediment, stoneline materials, and the underlying Wolf Creek Formation deposits (Figure 1). A later section will discuss

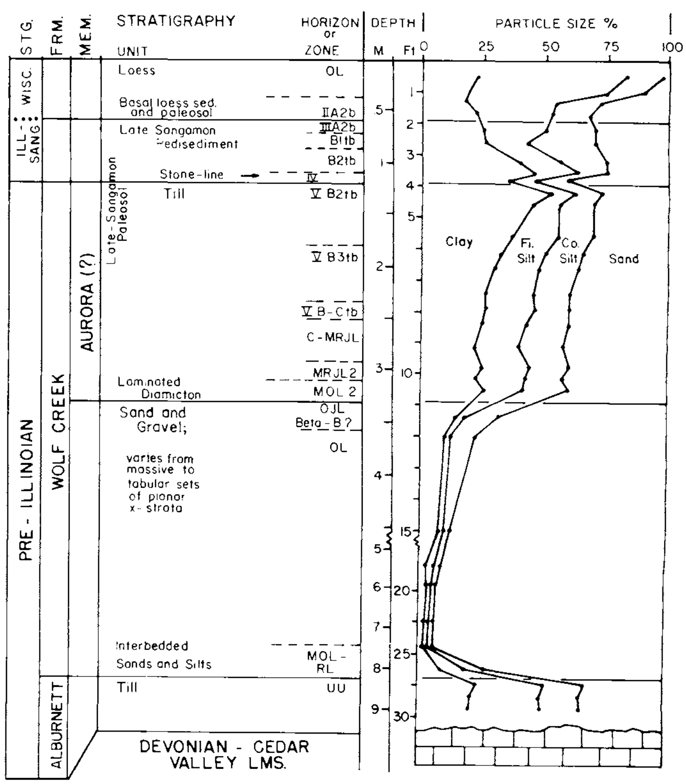

Fig. 2. Stratigraphy and particle-size data for 10m station (see Description 1 in Appendix).

properties of the pedisediment, stone line, and buried soil in detail.

The Upper Uniform Diamicton: The upper, uniform diamicton of the Wolf Creek Formation is texturally very homogeneous across the outcrop. Except for secondary weathering changes, it is dense, massive, and contains no stratified sediments or sedimentary structures indicative of flow or reworking.

The entire unit is weathered. Primary carbonates have been leached throughout. Some small cavities (or vugs) within the diamicton appear to be casts of former carbonate pebbles, with traces of insoluble residues on the bottom of the casts. Some secondary carbonate nodules are occasionally present near the base of this unit. They are subrounded to slightly oblate and range in size from 0.3 to 5cm in diameter.

Beneath the Late-Sangamon Paleosolum, the unit is mottled-oxidized and locally reduced. Reduced zones frequently occur near the base of the unit as pods or blocks bounded by oxidized joints.

There are numerous joints occurring throughout the unit (Figure 3). Various secondary changes occur along the joints, including illuvial clay coatings derived from the overlying Late-Sangamon Paleosol, reduced and oxidized zones along the joints, and secondary iron and manganese oxide coatings and nodules. Secondary changes are not the same along all of the joint sets. That is, some joints have thick zones (10cm) of secondary alterations along them, while other joints have only minor changes affecting only a thin zone next to the joint.

Three pebble fabrics were measured (Figure 4). The three fabrics are essentially identical, consisting of bimodal orientations with NW-SE and SW-NE maxima. Interpretation of these fabrics is difficult. First, it is uncertain how much the secondary weathering effects, which are significant for this unit, have altered the primary depositional fabric of the deposit. Second, bimodal fabrics have been reported in other studies of Pleistocene tills. However, the genesis of these tills were inferred rather than known with certainty, and the cause of the bimodal orientation was not known. We believe that the fabrics in the massive diamicton are relicts of the original depositional fabric. While the exact depositional process(es) of this unit cannot be inferred with certainty, the uniform fabric across the section,the uniform texture and composition, and the lack of any sedimentary structures indicative of flow or reworking strongly suggest that this unit has not been resedimented by subaerial sediment gravity flows, etc. We therefore classify this unit in the broad category of 'basal till,' following the usage of Dreimanis (1976) and Kemmis et al. (1981).

Because this upper, basal till unit is leached of carbonates, it cannot be analyzed for some of the properties that might allow correlation with paticular members of the Wolf Creek Formation. However, its texture, and the overall relations to more complete, multiple till sections in the area suggest that this is likely the Aurora Till Member.

This section also demonstrates problems which frequently occur in the study of older Pleistocene glacial deposits in the Midwest. First, the deposits are often significantly weathered, and standard sedimentologic study to determine the origin of the deposits can at best be difficult, particularly compared to the study of younger, less modified glacial deposits. Secondly, it appears that two of the three members of the Wolf Creek Formation, the youngest or Hickory Hills Till Member, and the oldest or Winthrop Till Member, are absent from this section. This is another common problem in studying older Pleistocene sequences: the record at any one section may be far from complete because the units are subject either to subsequent glacial erosion during later glaciations or to subaerial erosion during any of the various intervening interglacial periods (see Hallberg, 1980a, b).

Laminated Diamicton: The middle unit of the Wolf Creek Formation at Klein Quarry is a thin, 0.2 to 0.5m thick, unit of laminated diamicton. This unit consists of sub-horizontal, laminated to thinly bedded, heavy loam to light clay loam matrix with common pebbles and cobbles. Most of the inset clasts are very fine to medium pebbles, but clasts up to approximately 20cm in diameter have been observed.

In places the laminated diamicton is faulted. The faults are high-angle normal and reverse faults which extend down into the underlying sequence of stratified sand, silts, and gravel and then die out (Figure 1). The faults do not cut the overlying massive till; rather, the massive till drapes over the small fault offsets in plastic fashion.

The laminated diamicton is generally oxidized and has secondary weathering changes similar to the Wolf Creek Formation till that overlies it. Secondary carbonate nodules are present in the unit and are concentrated particularly at the base of the unit (Figure 3). The nodules are sub-rounded to oblate in shape, with the plane of their long and immediate axes sub-parallel to the lamination. Many of the nodules are large, with a-axis dimensions up to 15 to 20cm in length. Joints present in the overlying till persist into the laminated diamicton, and feature the same types of secondary alteration along them.

Two pebble fabrics were measured (Figure 4). In contrast to fabrics in the overlying till, the fabrics in the laminated diamicton are not systematic between sites, nor is there a strong preferred orientation at either site. This suggests that the laminated diamicton is not 'till,' a deposit which has inherited its properties directly from glacier ice (Lawson, 1981), but a resedimented deposit, one which was probably deposited in a standing body of water adjacent to glacier ice. The precise process by which the laminated diamicton formed is difficult

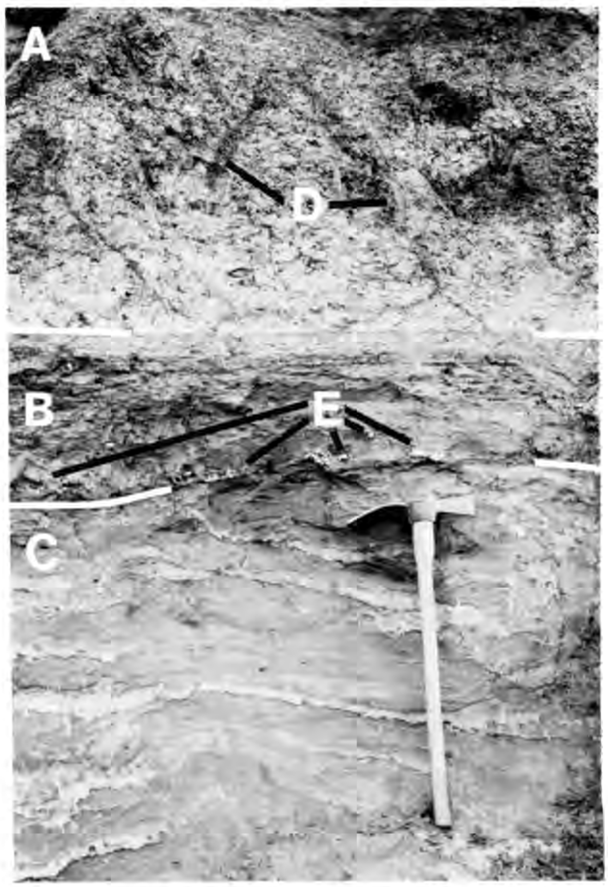

Fig. 3. Photograph of Klein Quarry exposure near 45 m station, showing: A. mottled, jointed (D), leached till; B. laminated diamicton; and C. deformed, stratified silts and sands of the Wolf Creek Formation. Note large (E) secondary carbonate concretions (white) at the contact between the laminated diamicton and the underlying stratified deposits.

to determine,and in fact there are a number of processes which could have taken place simultaneously to produce the bedding features present in the laminated diamicton unit. Eyles and Eyles (1983) discuss three end-member processes such as: 1) rain out (suspension fall-out from a water column); 2) rain out and current reworking; and 3) rain out with subsequent resedimentation (sub-aquatic sediment flows, etc.). Other possibilities include basal melting from a partially floating glacial terminus (Gibbard, 1980; Dreimanis, 1982) or icebergs, and subaqueous mass flow from a glacier terminus into a proglacial lake (Evenson et al., 1977; Dreimanis, 1982).

The Lower Stratified Sand, Silt, and Gravel Sequence: The lowest unit of the Wolf Creek Formation present at Klein Quarry consists of a stratified sequence of sands, silts, and gravels up to 5 m thick. The lower 3 to 4 m of this unit is not well exposed across most of the section and was not described in detail.

As in other fluvial and glaciofluvial sequences, the deposits in this unit vary considerably in both texture and bedding structures, laterally and vertically. In exposure the unit appears to be a generally fining-upward sequence. The lowermost portions of the unit tend to be dominated by large-scale cross-bedded, medium to coarse sands as well as sands and gravels displaying various cut and fill structures. The upper part of the sequence consists of thinner wedge sets of medium to fine sand, massive beds of sandy loam, and in places near the top, thin, discontinuous lenses of silt loam sediments. The nature of the 'fining upward,' then, is that there are no longer any gravel beds near the top, and beds of finer-grained sands, sandy loam, and silt loam sediments generally become more frequent (Figure 3). Occasionally a thin bed of finer-grained sands and silts occurs at the very base of the stratified unit as well.

The fluvial sequence is disconformably overlain by the laminated diamicton. Generally, the laminated diamicton exhibits an abrupt, planar contact with the sands, although locally it is more gradational.

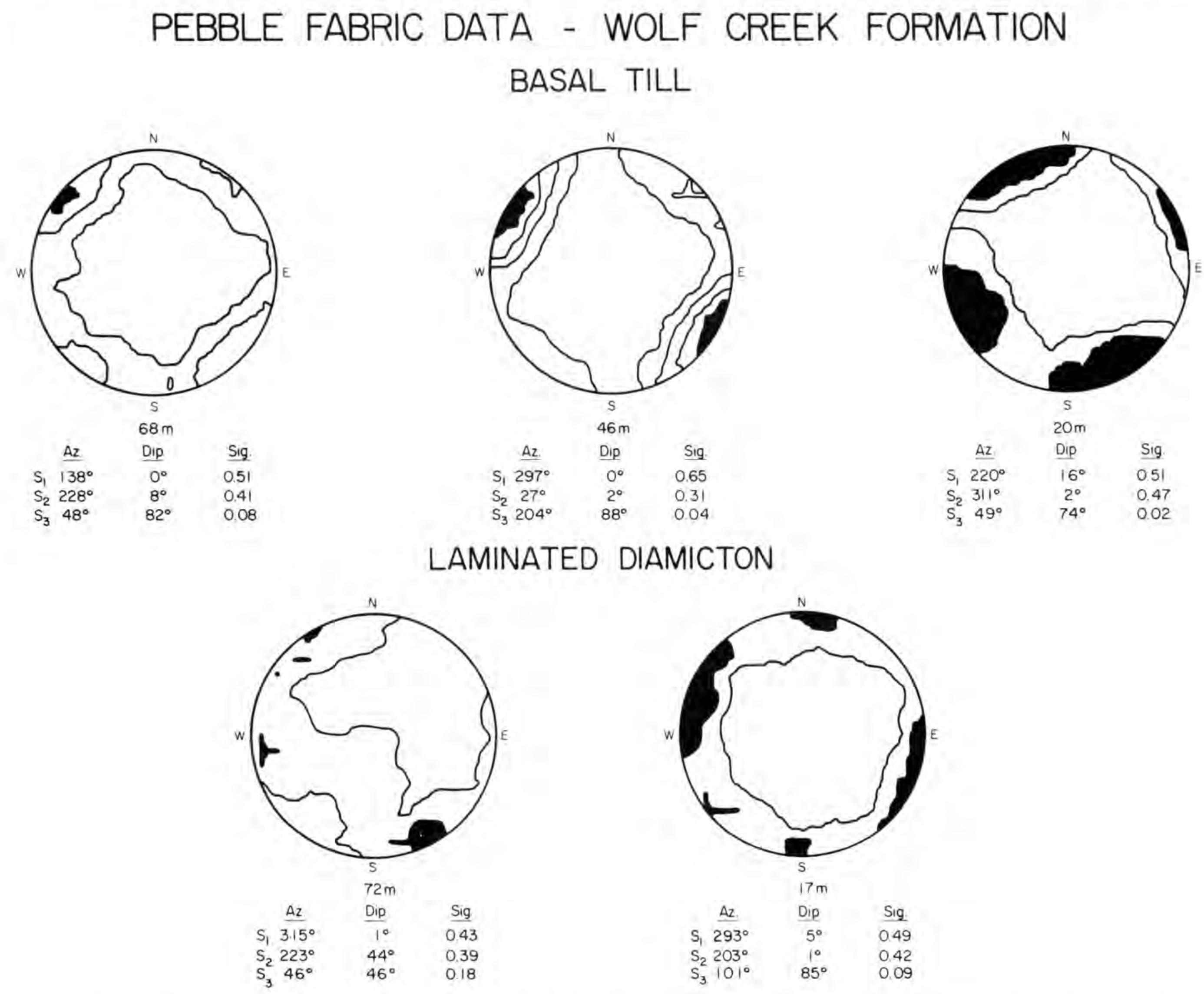

Fig. 4. Schmidt equal area nets contoured according to the method of Kamb (1959) at a countour interval of 2 ft. Eigenvector analysis data after Mark (1973) where $s_1 > s_2 > s_3$. Significance values sum to 1; thus, the numerical values give the relative magnitude for the respective eigenvectors. 68 m indicates station location along base line.

Occasionally, small-scale plastic deformation features occur at the contact. High-angle faults in the laminated diamicton extend down into the upper part of the stratified sequence, but generally are no longer apparent within one meter depth (Figure 1). In the upper part of the fluvial sequence some of the silt loam sediments have been deformed into diapir and flame structures which are a maximum of a meter high and one-half meter across. Some of these silt intrusions penetrate through interbedded sands and into the overlying laminated diamicton where they either terminate within the diamicton or end abruptly at the contact with the upper, uniform till unit.

This lower stratified unit is also weathered; primary carbonates have been leached throughout. The upper 30 cm of the unit are enriched and partially cemented with secondary clay and iron oxides. The clay enrichment decreases with depth, and from 30 to 70cm the clay occurs in very thin lamellae which become less closely spaced with depth. A similar enrichment of secondary clay and iron oxides also occurs in the lower 1.5m of the stratified deposits at the break between the upper interbedded sands and silts and the lower interbedded gravels and coarse sands. At the top of this interval, clay and iron lamellae increase in frequency and then, with depth, they permeate the coarse-grained matrix. This transition from clay-iron lamellae to intervals engulfed with secondary clay and iron oxides is a typical occurrence in Quaternary deposits, particularly where there is a textural or chemical discontinuity. These features are sometimes called Beta horizons or Beta B horizons in relation to weathering and soil development (Bartelli and Odell, 1960; Flach et al., 1969; Ballagh and Runge, 1970; Follmer et al., 1978; Miles and Franzmeier, 1981).

The stratified deposits are strongly oxidized and mottled. In places, secondary accumulation of iron and manganese oxides have formed "Liesegang banding' unrelated to the true bedding in the deposits. Some of the joints from the overlying till and laminated diamicton extend down into the stratified deposits. They are, however, fewer in number and often disappear with depth. While strong secondary alteration and clay deposition have taken place locally along the joints, it is noticeably less pronounced than in the till and laminated diamicton.

Paleoenvironmental Interpretation of Wolf Creek Formation Deposition at Klein Quarry: A complex sequence of deposits such as the Wolf Creek Formation units at Klein Quarry may, of course, be interpreted in a number of possible ways. The sequence and character of the deposits suggest that they are closely related in time. Our preferred interpretation is that the lower unit of stratified sands, silts, and gravels represents proglacial fluvial sediments deposited in front of an advancing continental glacier. Through time, this became a lower energy environment until it was a slackwater area, or "lake-like," as the glacier advanced very near the site. The laminated diamicton may then have been deposited in the lake as debris melted out either from a floating ice tongue or from small icebergs. The laminations thus would result from glaciolacustriune sedimentation, while the clasts may have been derived from rain-out and resedimentation from overlying floating ice. These events may have been followed by advance of the glacier into the lake basin and deposition, by grounded ice (on top of the laminated diamicton), of the upper unit of Wolf Creek Formation basal till. Faults in the laminated diamicton and the upper part of the stratified sequence, as well as the diapirically deformed silts, resulted from the loading imposed by the now grounded glacier at this site.

Of the three Wolf Creek Formation units at Klein Quarry, only the upper basal till unit (Aurora Till Member) is regionally persistent. The two lower units appear to represent only locally deposited sediments. The laminated diamicton is not present at any other exposure in the area. In fact,the laminated diamicton is the only deposit of its type of any age to have been reported or observed by the authors in Iowa.

Alburnett Formation

Alburnett Formation deposits are the oldest Pleistocene deposits present in the Klein Quarry exposure, and they occur as discontinuous units up to 1m thick (Figure 1, Appendix), locally preserved in various low areas on the underlying bedrock surface. The Alburnett deposits consist of a very dark gray, unoxidized, unleached, uniform, dense, unjointed massive diamicton. No pebble fabrics have been measured in this unit, but it strongly resembles basal tills found elsewhere in the area. The very dary gray color of this diamicton contrasts sharply with the mottled, weathered, oxidized and light-olive, reduced colors of the Wolf Creek Formation till higher in the section. The clay mineralogy of this lower till at Klein Quarry (Table 1) is typical of the Alburnett Formation in east-central Iowa (Hallberg, 1980a, b).

Underlying the Alburnett Formation deposits, or (where the Alburnett Formation is absent) the lower stratified unit of the Wolf Creek Formation, are Devonian-age carbonate rocks of the Cedar Valley Formation.

THE LATE-SANGAMON PALEOHILLSLOPE

The Klein Quarry section provides an excellent example of the Late-Sangamon (LS) pediment, as an erosion surface, and the LS Paleosol developed on the pediment. The erosion surface is marked by a conspicuous 'stone line' (Ruhe,1959), a lag gravel remaining after finer-grained matrix material was eroded away by various hillslope processes during cutting of the LS pediment. Going down the pediment from south to north (Figure 1), the erosion surface progressively truncates the upper Wolf Creek Formation till, the laminated diamicton, and part of the bedded sand and gravel sequence. At the far north end of the exposure (beyond Figure 1) the erosion surface may cut down to the till of the Alburnett Formation. However, the materials there are so altered by soil development that their identity is not clear.

Various components of the paleohillslope (Ruhe, 1969) are also exposed. From south to north the stone line slopes gently on the pediment surface, then the slope increases along a gentle backslope and then flattens out again in the footslope or footslope-fan position. In places below the upper pediment surface, the stone line dips and then rises abruptly in shallow, narrow sags that appear to mark former rills, or small gullies, on the LS hillslope. Overlying the stone line are thin, fine-grained, reworked hillslope sediments or 'pedisediment.' The pedisediment thickens downslope from the pediment into the footslope fan setting (Figure 1). The LS Paleosol is developed in the pedisediment, stone line, and the underlying Wolf Creek Formation deposits (Figure 1).

Various studies show that soil-profile characteristics on present hillslopes are closely realted to processes of hillslope sedimentation (Ruhe and Walker, 1968; Walker and Ruhe, 1968; Kleiss, 1969; Vreeken, 1972, 1975). Similar studies have seldom been done on paleohillslope systems (see Ruhe et al., 1967; Woodcock; 1979; Hallberg et al., 1980a, b; Follmer,1982). The data from Klein Quarry show that relationships between source material, hillslope sedimentation, and soil formation can also be recognized for such buried hillslope systems. However, most hillslope studies have been in areas where the hillslopes developed in a single, relatively 'homogeneous' stratigraphic unit; in contrast, the LS paleohillslope at Klein Quarry was developed across stratigraphic units of significantly different lithologies. The Klein Quarry exposure thus makes an excellent area to examine the relationship between hillslope stratigraphy and the properties of the stone line, the hillslope deposits (pedisediment), and the LS paleosol.

Properties of the Late-Sangamon Stone Line

Throughout Iowa, erosion surfaces on till are marked by a stone

Table 2. Selected measurements of Late-Sangamon pedisediment and paleosolum from four stations.

Station in m Along Baseline	Weighted Mean % Sand in Pedisediment	Co Silt	Fi Silt	Clay	Wtd. Mn. Fi Silt / Co Silt in PS	Fi Silt / Co Silt in A2b	% Sand	Co Silt	Thickness m		% Clay Max.	Clay A/B	Depth to Clay Max. m
10m	28.6	15.3	19.5	35.7	1.24	1.46	T) 29.5 A) 24.6 B) 26.7	18.8 12.6 10.6	P) 0.61 S) 1.78	H) 1.67	52.4	0.52	0.69
75m	33.4	14.6	19.7	32.7	1.29	1.94	T) 34.8 A) 33.0 B) 35.5	13.9 15.5 13.0	P) 0.71 S) 1.93	H) 1.73	38.4	0.57	0.74
100m	34.7	16.8	27.0	22.9	1.57	1.65	T) 31.0 A) 33.3 B) 43.5	20.3 15.9 14.5	P) 0.79 S) 1.98	H) 1.72	36.5	0.44	1.32
150m	38.4	11.7	19.3	36.9	1.60	2.0	T) 31.9 A) 48.7 B) 56.6	15.9 6.5 6.3	P) 1.22 S) 2.31	H) 2.04	37.8	0.47	0.94 *(1.42)

T - From A2b horizon, top of paleosolum
A - From 1st sample in pedisediment above stone line
B - From 1st sample below stone line

P - pedisediment thickness
S - paleosolum thickness
H - B horizon thickness

*Double clay maxima; see figure 9.

line, which is largely a lag of coarse gravel clasts remaining after the finer-grained matrix of the eroded glacial deposits has been removed. There are qualitative changes in the character of the LS stone line at Klein Quarry which provide insights about the evolution of the erosion surface. The upper part of the pediment cuts across the till and laminated diamicton of the Wolf Creek Formation. Here the stone line is well developed. Clasts are commonly angular, and vary widely in size up to 20cm in diameter (observed); similar to those present in the till.

Proceeding north, down the pediment onto the paleobackslope (Figure 1), the erosion surface truncates the till and the uppermost, finer-grained portion of the stratified sand, silt, and gravel sequence. The stone line on this portion of the erosion surface is still well expressed. However, it is comprised dominantly of small, moderately well-rounded pebbles that are fewer in number than in the stone line on the till, reflecting the smaller gravel size, lower gravel content, and the more well-rounded gravel in the upper stratified sand, silt, and gravel sequence. Scattered large, angular clasts, apparently derived from the till upslope, are present in the upper portions of the stone line, indicating that some restricted downslope movement of the clasts has taken place.

The stone line is comprised of larger clasts and becomes very pronounced where it cuts across gravel beds in the lower part of the fluvial sequence. At the north end of the exposure (Figure 1) the stone line is very weakly expressed. Here it is developed on some fine-grained deposits which contain very few clasts.

The properties of the stone line reflect a combination of source material and hillslope transport processes. The stone line is best developed on material with common clasts. Only on the steepest slope of the erosion surface is there much evidence of downslope transport of the clasts. This confirms prior hypotheses (Ruhe, 1967) that the stone line is essentially a lag deposit, resulting from the cutting of the erosion surface by relatively incompetent hillslope processes such as slope wash. Further, as the stone line (lag) evolved, it would have acted like "armor" (much like an armored stream bed), preventing much further downcutting. Also, the rough "bed" that the stone line created would likely affect the transport of sediment until the stone line was buried by pedisediment. Thus, at any particular point on the hillslope, the lowermost pedisediment should reflect little transport and sorting compared to the pedisediment above it at that point in the section.

Properties of the Late-Sangamon Pedisediment

Overlying the stone line is the thin increment of fine-grained pedisediment. The pedisediment varies systematically in thickness (Table 2) down the LS paleohillslope. It is thin (0.5m) across portions of the upper pediment, but progressively thickens to nearly 1.5m in the LS footslope position. The pedisediment is nearly free of pebbles and clasts and was derived from cutting of the LS erosion surface. The pedisediment is part of the fine-grained materials eroded by various hillslope processes (e.g., slope wash) during formation of the stone line (i.e., cutting of the pediment) further upslope.

There are various ways to analyze the particle-size characteristics and sorting of the pedisediment. Previous studies of modern hillslopes in Iowa (Kleiss, 1970; Walker and Ruhe, 1968) have shown that the distribution of coarser particles in hillslope deposits or pedisediment is primarily related to hillslope sedimentation processes, while the distribution of finer particles (clay, in particular) is primarily related to pedogenic processes. In these studies, surficial sediments (pedisediment) were shown to become systematically finer textured downslope, particularly on gentle hillslopes.

To evaluate the textural properties of the LS pedisediment and paleosol, samples were collected from four stations along the Klein Quarry paleohillslope (Table 2). Throughout the paleosolum, samples were collected at vertical intervals of 10cm or less.

These data were then analyzed in two ways. The first was to determine weighted-average values for the entire pedisediment interval at each of the four stations using mean-weighted sand content (MWS, Figure 5) and mean-weighted coarse silt (MWCS, Figure 6) and fine silt (MWFS, Figure 6), similar to these previous studies of

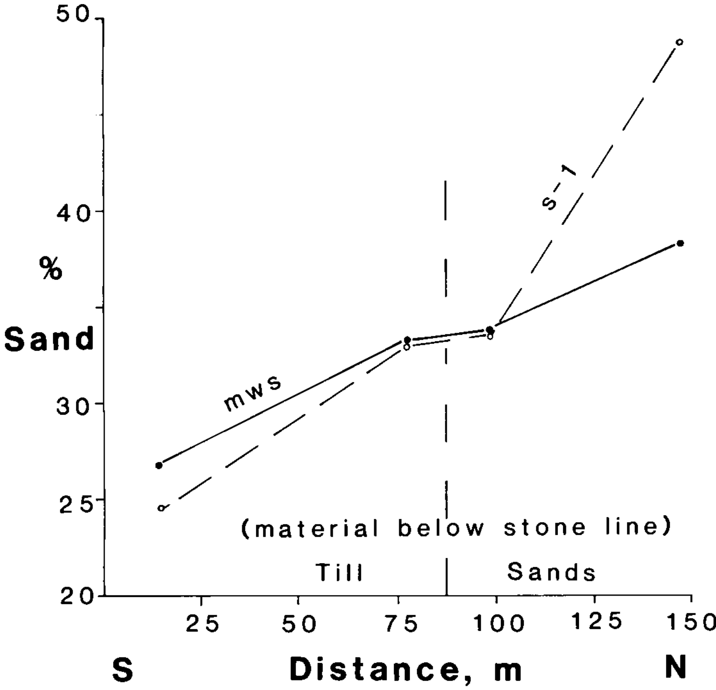

Fig. 5. Percent sand in pedisediment verus distance down the Late-Sangamon slope (from left-origin, to right): MWS — mean-weighted sand in pedisediment; S-1 — sand in first sample above stone line.

modern hillslope sediments. The data do not show the systematic fining trends downslope that the previously cited studies of modern hillslopes have. The mean-weighted sand content (MWS) in the LS pedisediment progressively increases going downslope, with an inflection in the trend at about 85 m (Figure 5). The mean-weighted coarse and fine silt contents are similar at 10 and 75m, then between 75 and 100m they increase, while from 100 to 150m they decrease 5 to 8 percent (Figure 6). In each case the marked change in textural properties of the pedisediment corresponds to the change in the material that the erosion surface is developed upon, which is till from 0 to 85m and the stratified sequence of sand, silts, and gravel from 85 to 150m. As the evolving hillslope-erosion surface encounters and truncates new materials, the character of the derived eroded debris should change. This, in turn, will effect any systematic patterns of sorting in these sediments (Kleiss, 1969) which might be apparent in weighted-mean textural data which integrate the full thickness of the sediment (Figures 5 and 6).

Thus, a second method was used to assess the influence of local source materials and the effects of sorting by hillslope processes on the properties of the pedisediment. The downslope trends of both the lowermost pedisediment samples (Figure 7) and uppermost pedisediment samples (Figure 8) were examined. If the underlying stratigraphy influences pedisediment texture, the lowermost pedisediment samples, like the stone line materials, should best show this. Figure 7 shows the relationship between the sand and coarse silt content in the lowest sample of pedisediment (immediately above the stone line) and the material immediately beneath the stone line. There is an excellent fit between the texture of the source material and the resultant pedisediment. The values from the particular stations also follow the same trends as the mean-weighted data for the entire pedisediment increment (Figures 5 and 6): sand content continually increases in both the source materials and the pedisediment, but the coarse silt content varies with that of the changing source materials downslope.

In contrast to the data from the lowermost pedisediment samples, the sand and coarse silt composition of the top of the pedisediment (the IIIA2b or 3Eb horizon) appears to be unrelated to that of the underlying source material, i.e., the material below the stone line (Figure 8). The percent sand in the upper pedisediment varies only slightly downslope, and appears unrelated to the material below the stone line. The coarse silt varies only 5 to 7 percent across the slope, perhaps reflecting downslope source material change, but in a very subdued fashion (compare to Figure 7). The relative homogeneity in the distribution of the coarse fraction in the upper pedisediment may be related to greater sorting and reworking of this increment of the pedisediment by hillslope processes.

Kleiss (1969) suggested that the systematic downslope increase in the ratio between fine silt and coarse silt (F/C ratio) of surficial sediments indicated differential sorting of the sediments by hillslope processes. The F/C ratios for LS pedisediment at Klein Quarry show complementary trends to the sand and coarse silt data (Table 2). The F/C ratios based on the mean-weighted particle size data for the whole thickness of the pedisediment increase only slightly downslope with a change in ratios corresponding to the lithologic changes at about 85m. The mean-weighted data suggest that the pedisediment has been little sorted and reflects the texture of the underlying source materials. However, the F/C ratios for the top of the pedisediment (A2b horizon, Table 2) show a much more pronounced increase downslope, again suggesting greater sorting by hillslope processes in the upper portion of the pedisediment.

These differences in properties and sorting, both vertically and laterally, within the pedisediment and stone line, assist in understanding the relationship of the pedisediment to the formation of the LS pediment. The evolution of the pediment (erosion surface) — pedisediment system is time-transgressive on a refined scale. Pediments evolve by headward slope retreat. The pedisediment is derived from the erosion of the pediment — both vertically and horizontally. As the

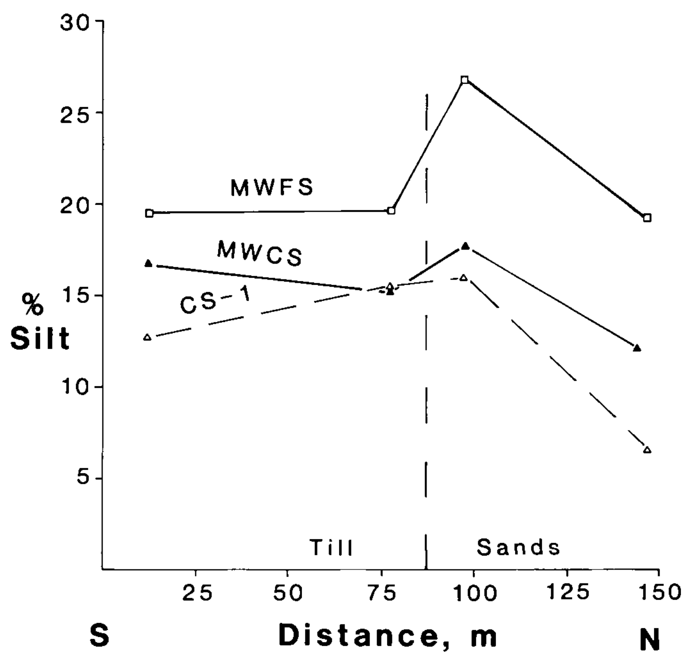

Fig. 6. Percent silt in pedisediment versus distance down the Late-Sangamon slope (from left-origin, to right): MWCS, MWFS — mean-weighted coarse and fine silt, respectively; CS-1 — coarse silt in first sample above stone line.

erosion surface was forming, the eroded debris would be transported (and sorted) across the pediment by sheet wash and other processes. As erosion progressed, a lag gravel or stone line would devleop which is time-transgressive upslope, and with time it would effectively armor the slope and slow down, or prevent further downcutting. As the stone line-pediment surface stablized, sediment derived upslope by active headward slope retreat is in part transported across the pediment surface and in part stored (deposited) on the pediment surface (as pedisediment). Sediment stored on the hillslope is clearly time-transgressive; obviously, younger pedisediment overlies older pedisediment. As hillslope processes continue to act, some of the stored pedisediment may be reworked and transported further downslope, and as the erosion surface grows upslope by cutting of the backslope into older land-surfaces (see Ruhe, 1967), new pedisediment may be transported downslope and deposited over somewhat older pedisediment. The "upper," younger increments of pedisediment should be farther traveled and may have been reworked several times, resulting in hillslope materials which are relatively better sorted and mixed.

The LS pedisediment at Klein Quarry reflects such an erosional and depositional history. The lowermost increment of pedisediment reflets the final cutting of the hillslope in that vicinity. It has not been transported a great distance nor has it been greatly sorted and reworked. It reflects the textural composition of the various underlyng source materials. The upper increments of pedisediment are progressively younger and no longer mimick the texture of the various underlying source materials; rather, they reflect both longer distance of transport and greater mixing.

These processes may also be reflected by the data in Figure 9. In this section (at 150 m), from the footslope-fan position where pedisediment is thickest, there is a progressive decrease in the sand content of the pedisediment upward from the stone line. The lowest part of the pedisediment reflects the character of the material underlying the stone line but then becomes progressively finer textured upward from the stone line, reflecting increased sorting and reworking of the material down the hillslope.

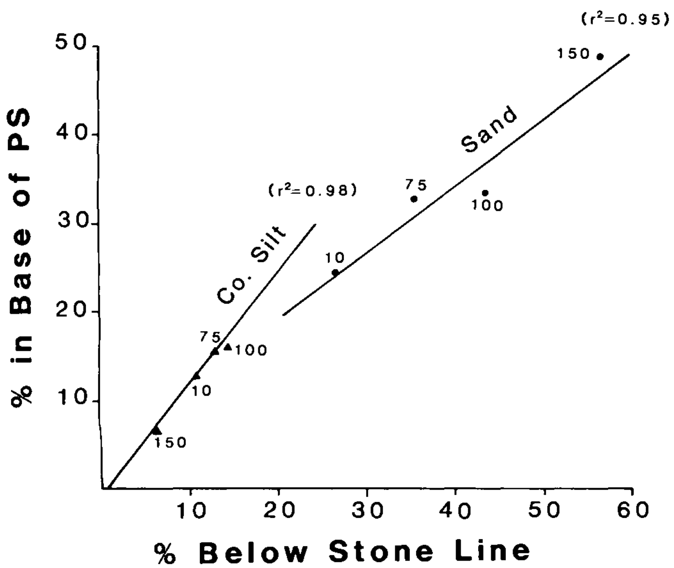

Fig. 7. Comparison of percent sand and coarse silt in material below the stone line to the material in first sample above the stone line (i.e., the base of the pedisediment). Number 10, 75, 100, 150, show station distance in m along base line where samples were taken (see Figure 1 and 5).

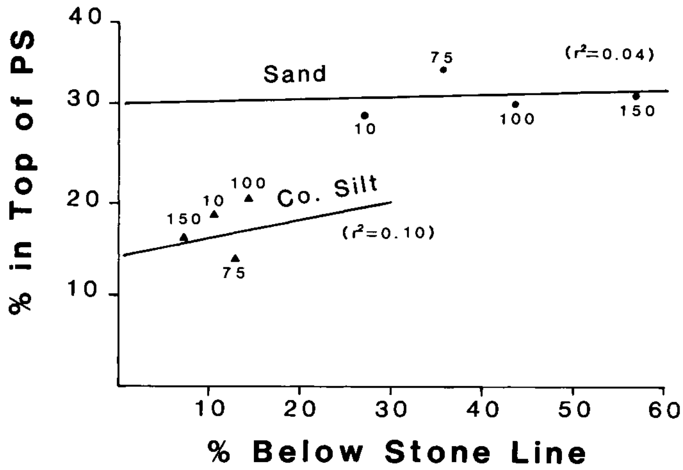

Fig. 8. Comparison of the percent sand and coarse silt in material below the stone line to the material in the topmost sample of pedisediment. (Conventions as in prior figures.)

It is also interesting to note that the particle-size distribution of the basal loess sediments generally reflect the same trends as the underlying LS pedisediment, except that the basal loess sediments are enriched in silt content. This and mineralogic data (discussed below) suggest that the basal-loess sediments are a mixture of loess and reworked pedisediment resulting from slope processes and pedologic mixing (Follmer, 1982) or welding (Ruhe and Olson, 1980).

Properties of the Late-Sangamon Paleosol

At some point in time the LS hillslope became relatively stable, and the LS Paleosol formed. The Klein Quarry section presents an interesting hillslope- or topo-sequence of soils on the LS surface. Going down the paleo-hillslope, the paleosol is developed in the pedisediment and the subjacent Wolf Creek Formation till, laminated diamicton, and the stratified silt, sand, and gravel sequence, and fine-textured alluvium (Figure 1). These changes in substrate materials and the sedimentological changes in the pedisediment described

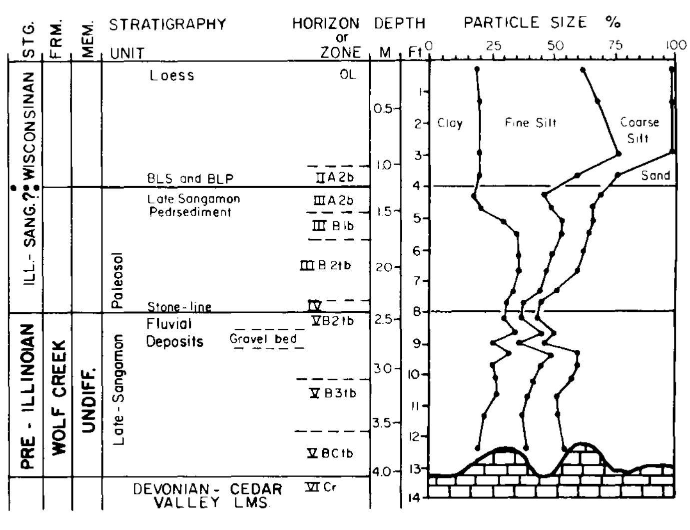

Fig. 9. Stratigraphy and particle-size data for 150m station (see Description 2 in Appendix).

above, also influence the properties of the LS Paleosolum across the paleohillslope. Detailed descriptions of representative end members of the LS Paleosol are given in the Appendix (Description 1 — 10m station on the pediment; Description 2 — 150m station on the footslope-fan), particle-size data are shown on Figures 2 and 9, and various paleosolum properties are summarized on Table 2. Some of the textural differences that occur are obvious in Figures 2 and 9, and in the detailed descriptions for these stations. Other changes in properties and morphology of the paleosolum occur, as well.

All across the slope, the LS Paleosol exhibits a (buried) A2 (E) horizon and a well-expressed argillic B horizon. The soil colors and morphology suggest that all these LS soil profiles were well drained. At the north end of the section (150m station; Figure 9; Description 2) stronger mottling is apparent which may be related to greater moisture fluctuations from the run on and throughflow that occurs in footslope positions.

Some clay coatings and bright iron-oxide mottles occur along subangular blocky peds within the A2 (E) horizon of the LS Paleosol. These are B-horizon characteristics and are probably not related to LS soil development, per se. The imposition of these minor B-horizon traits likely occurred as the A2 (E) horizon of the basal-loess paleosol formed as part of this complex buried soil profile. After the thin increment of basal-loess sediments was deposited (and during deposition?) an A2 (E) horizon (the IIA2b or 2Eb, see Descriptions) formed in the basal-loess sediments (basal-loess paleosol). Thus the A2 (IIIA2b or 3Eb) of the LS Paleosol underwent subsequent development as the B horizon of the basal-loess paleosol, Late-Sangamon Paleosol complex. Soil development of this complex persisted until burial by the thick increment of Wisconsinan loess.

The B horizon (III Bb or 3Bb) of the LS paleosol is argillic and shows strong morphologic expression. Peds in the upper part of the B horizon have relatively thick, continuous coatings of illuvial clay. Even on the pediment the B horizon begins within the pedisediment. For example, at the 10m station (Figure 2; Description 1) the zone of maximum clay enrichment is thin but pronounced, reaching 45% in the base of the pedisediment and a maximum 52% in the top of the till. The ratio of percent clay in the A horizon to percent clay in the B horizon (A/B ratios, table 2) is relatively constant where the paleosol is developed in pedisediment over till and where the paleosol is developed in pedisediment over stratified deposits. The B horizon has a strong subangular blocky structure. This subangular blocky structure becomes more coarse with depth. In detail, the horizon is complexly mottled (see Descriptions), but the prominent overall impression is the "dark reddish-brown" matrix color which is characteristic of the B horizon of the LS Paleosol across the outcrop.

As noted, one of the more obvious changes that takes place downslope is that the pedisediment systematically increases in thickness (Table 2; Figure 10). As it does so, the portion of the LS Bt horizon (textural B-horizon; with pronounced clay films and clay enrichment) developed in the pedisediment increases, and at the north end of the section the zone of maximum B-horizon morphology occurs in the pedisediment (Figure 9; Description 2). This is one of the many reasons that the pedisediment has been considered "Late-Sangamon" or at least pre-Wisconsinan in age in Iowa (Ruhe, 1967; 1969; 1976; Hallberg et al., 1978a). Although soil development continued on this surface into Wisconsinan-time, when the LS surface was buried by loess, the LS Paleosolum is fully developed in the pedisediment and this has precluded the correlation of the pedisediment with early-Wisconsinan deposits (Ruhe, 1967; 1976).

As the LS pedisediment thickens downslope so does the total thickness of the LS Paleosol (Figure 10). In fact, there is an excellent linear statistical relationship between pedisediment thickness and paleosolum thickness (Figure 11). Nearly all of the increase in paleosolum thickness is accounted for by increases in B-horizon thickness (Table 2). As the pedisediment and B horizon thicken

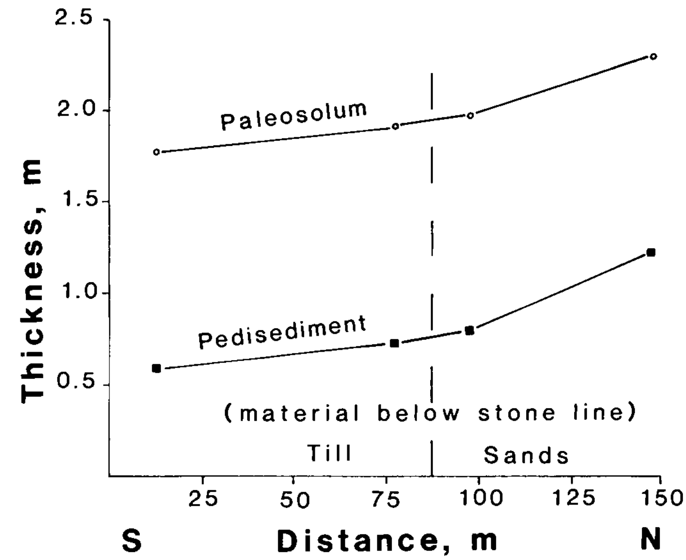

Fig. 10. Thickness of the pedisediment and paleosolum versus distance down the Late-Sangamon slope.

downslope, the maximum clay content in the B horizon generally decreases and the depth to the maximum clay content increases (table 2). In other words, the zone of clay enrichment is thicker but less pronounced as the pedisediment thickens and as the subsoil material changes to one of more coarse texture and likely of higher permeability. These relationships are complicated at the north end of the section in the paleo-footslope position (Figure 9) where two clay maxima occur (table 2) because of the stratification of the Wolf Creek Formation deposits.

X-ray analysis of clay fractions show various alterations and some interesting contrasts between the basal-loess paleosol and the LS Paleosol. In the thin basal-loess paleosol, smectite peaks are present but somewhat broadened and rounded from weathering alterations (see Hallberg et al., 1978c). Small vermiculite and illite peaks are present, as is a well-defined kaolinite (plus vermiculite) peak. By contrast, significantly greater alterations are apparent in the immediately subjacent IIIA2b (3Eb) horizon in the LS Paleosol: a smectite peak is not apparent, only a broad diffuse hump occurs; and no illite peak is present. The degree of clay mineral alteration decreases with

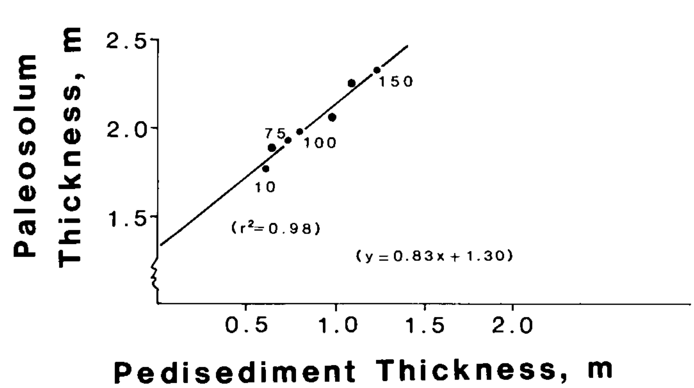

Fig. 11. Comparison of Late-Sangamon pedisediment thickness versus paleosolum thickness.

depth; illite reappears and in the lower B horizon all clay minerals show well-crystallized peaks similar in proportions to the underlying, less weathered till (Table 1).

The various pedologic and sedimentological relationships suggest that the LS erosion surface (pediment) — pedisediment — paleosol system evolved slowly and systematically with time. Pedisediment must have accumulated in the lower slope positions at a slow enough rate that soil development kept pace with sediment accumulation, resulting in thicker B horizons (Follmer, 1982).

SUMMARY

The exposures at the Klein Quarry afford a rare view of the LS erosion surface and paleosol and some unique Quaternary deposits. Unlike many exposures of Quaternary deposits, this exposure may be accessible for students of the Quaternary for some time, because of the quarry operations. This study shows that hillslope sedimentation patterns can be related to slopes which bevel multiple stratigraphic units, and that such relationships can be evaluated for buried hillslopes and paleosols.

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APPENDIX

Described soil morphology is necessary for the understanding of soils and paleosols. Thus, the detailed soil descriptions from the 10m and 150m station are presented. These descriptions are representative of the hillslope end members of the Late-Sangamon Paleosol in the Klein Quarry exposure.

Description 1. Section description in Klein Quarry at south end of exposure, at 10m station along baseline; section begins in the lowermost portion of the Wisconsinan loess (description by G. R. Hallberg, H. Canfield, R. Graeff).

Depth m (inches)	Horizon or Zone	Description
WISCONSINAN		
Wisconsinan loess		
0-0.38 (0-15)	OL	Dark yellowish brown (10YR4/4) silt loam; very few fine mottles; massive to very weak, medium platy structure; clear, smooth lower boundary.
Basal-loess paleosol		
Basal-loess sediments		
0.38-0.48 (15-19)	IIA21b (2E1b)*	Brown (10YR5/3) 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.
0.48-0.58 (19-23)	IIA22b (2E2b)	Mixed yellowish brown (10YR5/4-6, 10YR6/6), brown (10YR5/3); yellowish brown (10YR5/4, smeared mixture) loam (more sand than above); few fine, prominent, strong brown (7.5YR5/6) mottles; moderate thin platy, breaking to weak very fine subangular blocky; common, medium grainy coats (as above) on plates, friable; common fine charcoal flecks; clear, smooth lower boundary.
Late? SANGAMON		
Late-SANGAMON PALESOL		
Late-Sangamon Pedisediment		
0.58-0.69 (23-27)	IIIA23b (3E3b)	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.
0.69-0.81 (27-32)	IIIB1tb (3BEtb)	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.
0.81-0.99 (32-39)	IIIB21tb (3Bt1b)	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 lower boundary.
0.99-1.12 (39-44)	IIIB22tb (3Bt2b)	As above, but more clay; very strong fine subangular blocky; continuous thin, discontinuous moderate, and few thick clay films; abrupt lower boundary.
1.12-1.19 (44-47)	IVB22tb (4Bt3b)	Stoneline (gravelly clay loam) at contact between units.
Late-SANGAMON Paleosol		
PRE-ILLINOIAN		
Wolf Creek Formation		
Aurora (or Hickory Hills) Till Member		
1.19-1.35 (47-53)	VB23tb (4Bt4b)	Mottled dark brown (7.5YR4/4), strong brown (7.5YR5 and 4/6) yellowish red (5YR5 and 4/6), 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 moderate, common thick clay films; very firm; gradual lower boundary.
1.35-1.50 (53-59)	VB25tb (5Bt5b)	As above; with few, medium, dark gray and gray mottles and coatings; slickensided pres-

		sure faces on thick clay coatings along vertical cleavage planes; abrupt lower boundary.
1.50-1.75 (59-69)	VB25tb (5Bt6b)	Dark yellowish brown (10YR4 and 5/4) and light olive brown (2.5Y5 and 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, few thick films, some peds with bare interiors; firm; common pressure faces on vertical cleavage planes; gradual lower boundary.
1.75-1.98 (69-78)	VB31tb (5Bt7b)	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.
1.98-2.11 (78-83)	VB32tb (5Bt8b)	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; nearly continuous thin clay films; clear, wavy, lower boundary.
2.11-2.36 (83-93)	VB33tb (5BCt1b)	Yellowish-brown (10YR5/6) heavy clay loam with pebbles; common manganese oxide coatings as above; strong medium subangular blocky; common thin clay films; diffuse, irregular boundary.
2.36-2.49 (93-98)	VC-Btb (5BCtb)	As above; moderate medium subangular blocky; wavy, irregular transitional horizon.
2.49-2.92 (98-115)	VC(5C)-MRJL	Light olive brown (2.5YR5/4) loam with pebbles; common yellowish brown (10YR5/6-8), brown (10YR4/4), 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.
2.92-3.10 (115-122)	MRJL2	As above, with few secondary carbonate concretions; abrupt lower contact.

Laminated diamicton

3.10-3.28 (122-129)	MOL2	Yellowish brown (10YR5/6), light olive brown (2.5YR5/4), and strong brown (7.5YR5/6), bedded loam with pebbles; colors concentrated along thin beds (2-10mm thick); separates along beds and breaks to moderate subangular blocky; common coarse very dark gray (5YR3/1) manganese oxide coatings; few secondary carbonate concretions; abrupt lower contact; laminated diamicton horizon.

Wolf Creek Formation
Undifferentiated sand and gravel

3.28-3.56 (129-149)	OJL-Beta horizon?	Strong brown (7.5YR-10YR5/6), sandy clay loam with no pebbles; common brown (7.5YR5 and 4/4) and brownish yellow (10YR6/6) mottles; massive, jointed, partially cemented with iron-oxides and clay, few thin clay films; slightly firm; gradual wavy lower boundary.
3.56-3.66 (140-144)	OJL	Mixed yellowish brown (10YR5/6) and light olive brown (2.5Y5/6), sandy loam to loamy sand; common brown (7.5YR4/4) and yellowish red (5YR4/6); massive; joints die out; friable; gradual boundary.
3.66-3.96	OL	Yellowish red (5YR5/6-8) medium sand; loose sand with thin, horizontal clay lamellae, which become less frequent with depth.
		Abbreviated description to 9.1m
3.96-4.76 (156-187)	OL	Medium to coarse sand; massive, little bedding apparent.
4.76-5.66 (187-223)	OL	Coarse gravelly sandy loam; near horizontal, planar bedding.
5.66-6.68 (223-263)	OL	Alternating tabular beds (0.15-0.70m thick) of cross-bedded coarse sand, and sand and gravel, and planar-level bedded fine sands.
6.68-7.38 (263-290)	OL (Beta-horizon?)	As above, but with iron and manganese oxide cements, some clay coatings; cross-beds and imbrications indicate flow from north northwest; few till balls included.
7.38-8.20 (290-323)	MOL-RL	Thin interbeds of MOL-RL silt, and OL fine sand; sand partially cemented with iron oxides and clay.

Alburnett Formation
Undifferentiated Till

8.20-9.10 (323-358)	UU	Dark gray (5Y4/1) to dark greenish gray (5GY4/1) loam till; weakly calcareous.

*Horizon designations in parentheses are new horizon symbols in use by U.S. Soil Conservaton Service.

Description 2. Section description in Klein Quarry at north end of exposure at 150m station along baseline; section begins in lower part of Wisconsinan loess (description by Howard Canfield and G. R. Hallberg).

Depth m (inches)	Horizon or Zone	Description
WISCONSINAN		
Wisconsin loess		
0-1.07 (0-42)	OL	Yellowish brown, (10YR5/4) silt loam; few reddish yellow (7.5YR6/8) mottles and few fine very dark grayish brown mottles (10YR3/2); massive to very weak thin platy; common root tubules; clear, smooth lower boundary.
Basal-Loess Paleosol		
Basal-loess sediments		
1.07-1.20 (42-47)	IIA21b (2E1b)	Brown (10YR5/3) silt loam (more sand than above); few, faint strong brown (7.5YR5/8) mottles; moderate, coarse prismatic breaking to weak fine subangular blocky; common root tubules; friable; few charcoal flecks; clear smooth boundary.
Late? SANGAMON		
Late-Sangamon Paleosol		
Late-Sangamon Pedisediment		
1.20-1.35 (47-53)	IIIA22b (3E2b)	Brown (10YR5/3) loam; common yellowish red (5YR5/3) mottles; moderate coarse pris-

		matic, breaking to moderate thin platy and fine subangular blocky; common root tubules; common black charcoal flecks; friable; clear smooth boundary.
1.35-1.47 (53-58)	IIIA23b (3E3b)	Mottled yellowish brown (10YR5/6) and faint yellowish red (5YR5/8) loam; medium prismatic, breaking to moderate thin platy and fine subangular blocky; root tubules; friable; charcoal flecks; clear smooth lower boundary.
1.47-1.65 (48-65)	IIIB1tb (3Bt1b)	Strong brown (7.5YR5/6) and yellowish brown (10YR5/6) clay loam; few faint black (2/1) mottles; moderate very fine subangular blocky; few red clay coats (2.5YR4/6); friable; few charcoal flecks; gradual, smooth lower boundary.
1.65-2.01 (65-79)	IIIB21tb (3Bt2b)	Red-yellowish red (2.5YR-5YR4/6) clay loam; moderate very fine subangular blocky; nearly continuous red clay coats (2.5YR4/6); friable; firm; gradational lower boundary.
2.01-2.34 (79-92)	IIIB23tb (3Bt3b)	Red-yellowish red (2.5YR-5YR4/6) clay loam; moderate-strong fine subangular blocky; continuous thin red clay coats (2.5YR 4/6); occasional thick clay coats; firm; friable; abrupt lower contact.
2.34-2.41 (92-95)	IVB23tb (4Bt4b)	Stone line; gravelly, sandy clay loam; contact between units.

Late-SANGAMON Paleosol
PRE-ILLINOIAN
Wolf Creek Formation
undifferentiated glaciofluvial deposits

2.41-2.69 (95-106)	VB24tb (5Bt5b)	Red (2.5YR4/6) sandy clay; moderate to strong very fine subangular blocky; continuous red clay coats (2.5YR4/6); friable; abrupt lower boundary.
2.69-2.82 (106-111)	VB25tb (5Bt6b)	Red (2.5YR4/6) gravelly sandy clay loam; as above; gravel bed.
2.82-3.05 (11-120)	VB26tb) (5Bt7b)	Mottled, Yellowish red (5YR4/8) clay loam; mottled; common distinct black (5YR2/1) mottles; few faint strong brown (7.5YR5/6) and black coats (5YR2/1); strong medium to fine subangular blocky; continuous red (2.5YR5/8) clay coats, occasional thick clay coats on vertical pressure faces; firm, abrupt lower boundary.
3.05-3.23 (120-127)	VB31tb (5Bt8b)	Mixed strong brown (7.5YR5/6) and light brownish gray (2.5Y6/2) loam; distinct, abundant black (7.5YR2/1) mottles, common brownish yellow (10YR6/8); yellowish red (5YR5/8) and olive yellow (2.5Y6/8); moderate, medium subangular blocky structure; common red (2.5YR4/6) clay coatings, common bare ped faces, occasional distinct black (7.5YR2/1) manganese coatings; occasional vertical pressure faces with slickensides; clear lower boundary.
3.23-3.40 (127-134)	VB32tb (5BCt1b)	Mixed colors as above; moderate medium to coarse subangular blocky; occasional red clay coats (2.5YR4/6), common black mangans; firm; clear lower boundary.
3.40-3.76 (134-148)	VB33b (5BC1b)	Mottled, mixed color loam, as above; weak medium subangular blocky; common black mangans; firm; irregular lower contact, material and soil extend down into fractures and voids in Devonian limestone below.

Late-SANGAMON Paleosol
DEVONIAN
Cedar Valley Formation

3.76-3.86 (134-152)	VICr (6Cr1b)	Soft, weathered rind on limestone.
3.86- (152-)	VIR (6R)	Limestone.