AFTER THE GREAT FLOOD

Exposures in the Emergency Spillway, Saylorville Dam

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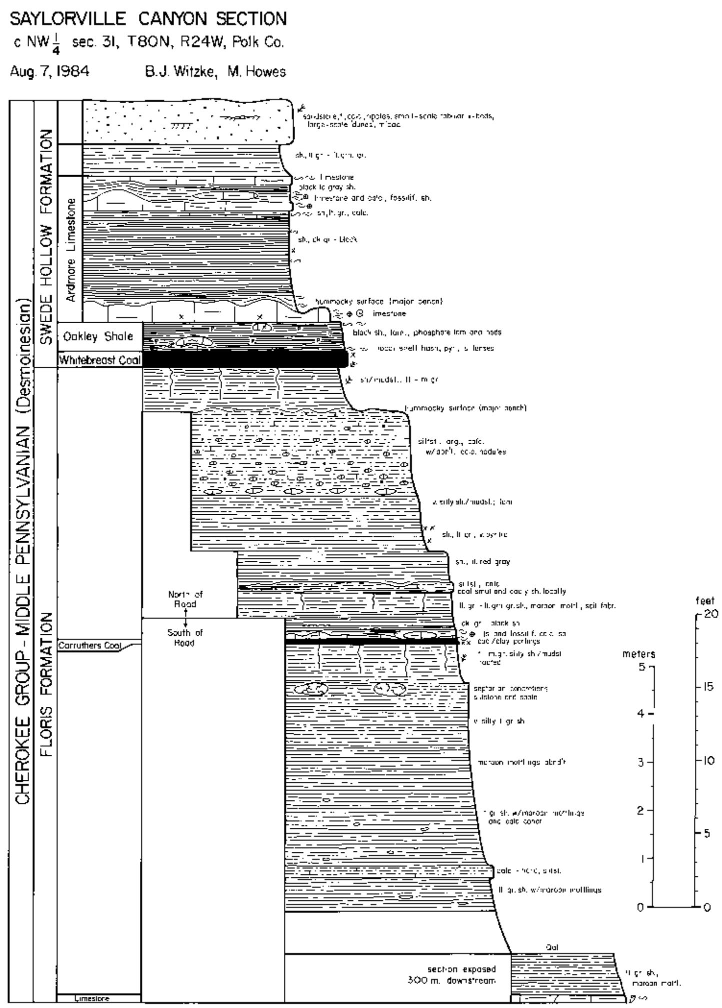

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OVERVIEW

HISTORY OF THE EMERGENCY SPILLWAY AND ORIGIN OF THE EXPOSURES

Information presented in this section was obtained from Saylorville Dam Supplement to Periodic Inspection Report No. 7: Initial Overflow of Spillway June-July 1984, Rock Island District, U.S. Army Corps of Engineers

Construction

For those unfamiliar with the general design features of large earthen dams like Saylorville Dam, an emergency spillway is provided to help alleviate high reservoir levels that might potentially promote dam failure through excessive seepage pressures or overtopping. The emergency spillway is located on the west side of the dam and joins the Des Moines River downstream of the outlet works (Fig. 2-1). The spillway was constructed in three phases beginning in 1965. During Stage I much of the borrowing from the area was completed. The spillway was located so as to use part of a pre-existing tributary valley to the Des Moines River.

During Stage II additional grading was completed and downstream portions of the tributary valley were filled. Horizontal drain pipes were installed in the right (west) spillway bank below where the present access road crosses the spillway. Drainage of this area was needed to ensure slope stability in an area where large-scale natural slumping was evident.

Stage III consisted of final spillway excavation and correction of the slope instability problem in the right backslope of the spillway. All work on the emergency spillway was completed by November, 1975.

The main features of the spillway are: an uncontrolled gravity concrete ogee weir, 137 m (450 ft) wide, flanked with gravity bulkhead sections; 61 m (200 ft) of paved chute; and approximately 1,524 m (5,000 ft) of unlined trapezoidal chute. The paved chute is anchored to the underlying Pennsylvanian-age sandstone (Swede Hollow Fm.) with concrete anchors. Portions of the 'unlined' trapezoidal chute were underlain by thick sandstone which acted as a natural 'paved' chute. The original profile of the spillway is shown on Figure 1.

After grading of the spillway and installation of the weir, topsoil was added to the bedrock surface of the spillway channel above the access road crossing. The purpose of this cover was twofold: to protect the bedrock from erosion and weathering, and to provide a medium for vegetation growth.

1984 Overflow Event

Events leading up to the onset of discharge through the emergency spillway started with heavy spring rainfall leaving the reservoir 42% filled at the beginning of June. April rainfall in the Des Moines River Basin was 114%

above normal followed by 7% above normal in May and 68% above normal in June. These above normal rainfalls caused the reservoir level to reach the emergency spillway crest elevation of 884 ft on Monday, June 18, 1984.

During the first day of overflow most of the small trees in the channel area remained in-place and upright. A bulldozer cut was made across the access road to provide a notch for the start of the breach, since the embankment was to be overtopped. Early on the second day water began to back-up behind the road embankment and began to flow down the road toward the outlet works discharge channel of the dam. Temporary diking and additional bulldozing forced the flow back through the notch and the road embankment finally eroded away near the channel centerline. Flow at this time was approximately 7,000 cfs.

Signficant erosion (incision and headward migration) of the spillway channel began by the third day. By that time the steep area in the vicinity of the access road was whitewater. Just downstream, in the vicinity of Section 10 (Fig. 2-1), flow was diverted away from the right (west) bank and into the left bank (Section 2, Fig. 2-1) by dense Pre-Wisconsinan deposits. Deposits along the left bank were more easily-eroded, particularly the recent fill, which had been emplaced during spillway construction to fill the small side valley that crossed the emergency spillway. By day 4 (June 21, 1984) most of the trees had been swept away from the spillway channel and headward erosion of the steep reach in the vicinity of the access road continued.

The pool crested at the highest level of 889.3 ft on day 6, Friday, June 23. At that time flow over the emergency spillway was 17,000 cfs. Flow velocities were in the range of 7.5 fps from the weir to the sandstone ledge. From that point to below the access road, flows descended down the spillway channel in supercritical flow regime with considerable turbulence. Significant downcutting occurred slightly above the access road and throughout the lower reach of the spillway channel. The fast moving, turbulent water crashed against vertical walls of the channel causing further cutting, slumping, and loss of material.

The overflow event continued for another 10 days leaving an eroded rectangular- to V-shaped channel with vertical walls as high as 10 m (30 ft). The downcutting fostered further slope instability, particularly along the right bank of the spillway. This failure occurred as shallow slips and failures initiated in the upper portions of the Pennsylvanian rocks which in turn involves overlying late Wisconsinan-age alluvium. Several large nested slump blocks with large surface cracks extending up the right bank (western slope) are evident today.

Approximately 277,000 cubic yards of material were eroded from the emergency spillway channel during the overflow event. Erosion of the Pennsylvanian strata was fostered by undercutting of the more resistant beds (limestone and sandstone) followed by rotation and topling of individual blocks along joints. Quaternary deposits in the spillway channel are generally less resistant to erosion than the Pennsylvanian deposits. The channel downcut rapidly in these deposits and undercutting and slumping of nearby vertical sidewalls was common.

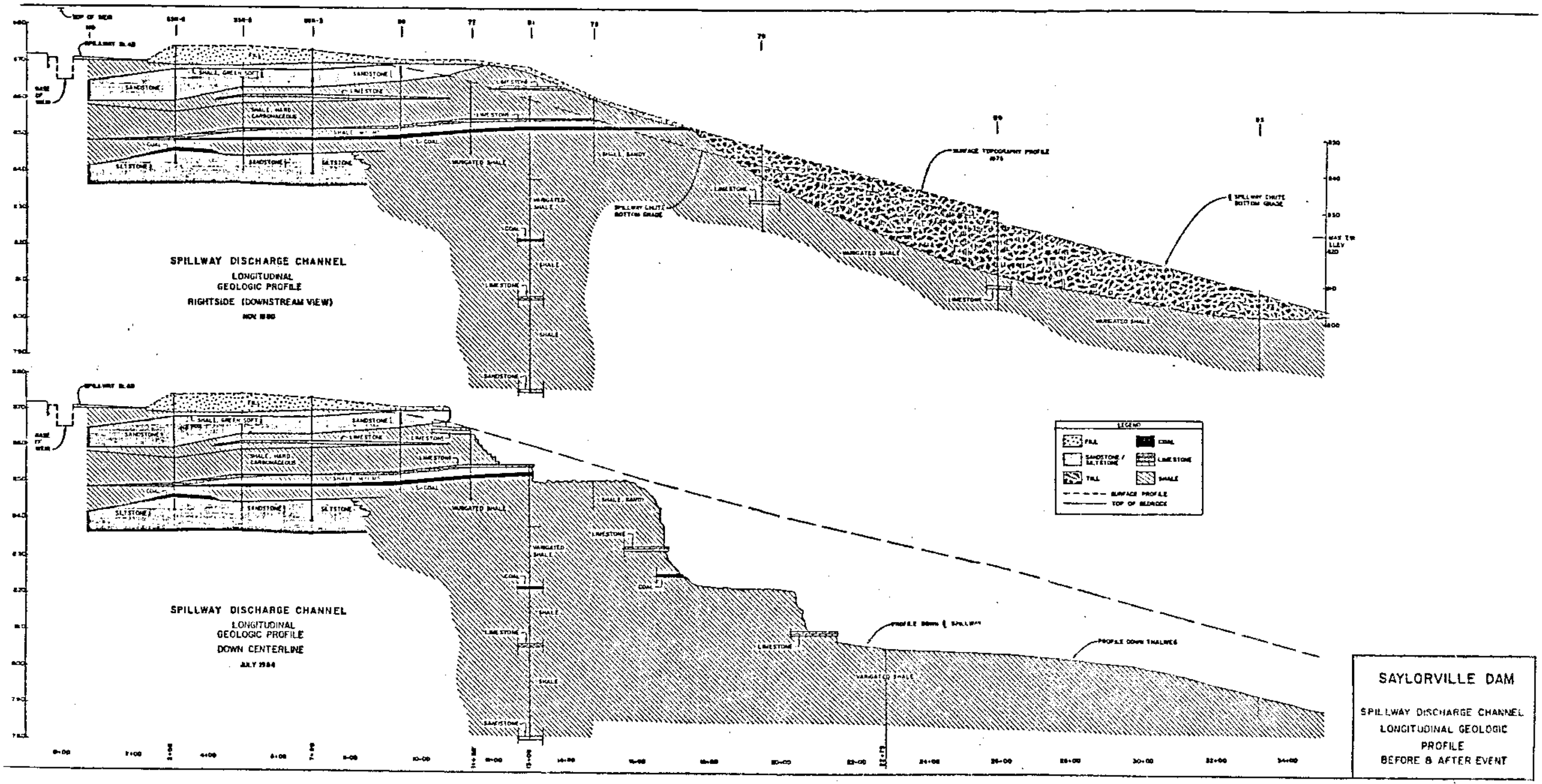

Figure 1. Longitudinal section along the centerline of the Saylorville Emergency Spillway channel before (upper) and after (lower) the June, 1984 overflow event. Adapted from Plate 13 in Saylorville Dam Supplement to Periodic Inspection Report No. 7: Initial Overflow of Spillway June-July 1984, Rock Island District, U.S. Army Corps of Engineers.

PART 1. PENNSYLVANIAN STRATA EXPOSED IN THE SAYLORVILLE EMERGENCY SPILLWAY

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Introduction

A thick sequence of Middle Pennsylvanian strata was exposed by rapid downcutting as floodwaters surged through the emergency spillway of Saylorville Dam during June, 1984. These strata, part of the Cherokee Group, range upward from the mid-Floris Formation through strata above the Ardmore Limestone Member of the Swede Hollow Formation (Fig. 1-1). The stratigraphic nomenclature used in this report is the recently revised nomenclature for the Pennsylvanian of Iowa (Ravn et al., 1984).

This exposure is the best (and most accessible) exposure of this stratigraphic interval in Iowa. It is of particular interest for several reasons. First, the lower part of the Swede Hollow Formation, including the Whitebreast Coal, Oakley Shale, and Ardmore Limestone Members, is the oldest widely traceable sequence of units in the Pennsylvanian of Iowa. Correlative units extend across much of the midcontinent region, possibly as far east as Ohio, making it the most laterally continuous sequence of units in the Pennsylvanian of North America.

Secondly, Oakley-Ardmore deposition probably marked the first complete marine inundation of the Iowa area during the Pennsylvanian. Although older marine units are known from the Pennsylvanian of Iowa, none are as thick or laterally persistent as those in the lower Swede Hollow Fm. The Swede Hollow sequence closely resembles cyclic repetitions (cyclothems) of marine and nonmarine units in the younger Marmaton Group (Heckel, 1979).

Third, two distinct depositional regimes are represented in this exposure. The clastic units of the upper Floris Formation are primarily nonmarine, fluvial-deltaic sediments (except the thin limestones found above the coals). In contrast, the Swede Hollow portion of the outcrop is a transgressive-regressive marine sequence.

Description of Pennsylvanian Outcrop At 'Saylorville Canyon'

Figure 1-2 is a diagramatic representation of the Pennsylvanian sequence exposed at 'Saylorville Canyon'. The strata occur in three sections exposed along the upper reaches of the Saylorville Emergency Spillway. Two of the exposures occur south of the access road crossing the emergency spillway and one occurs north of the access road. The following discusses the properties of strata exposed in the emergency spillway, beginning with the oldest units.

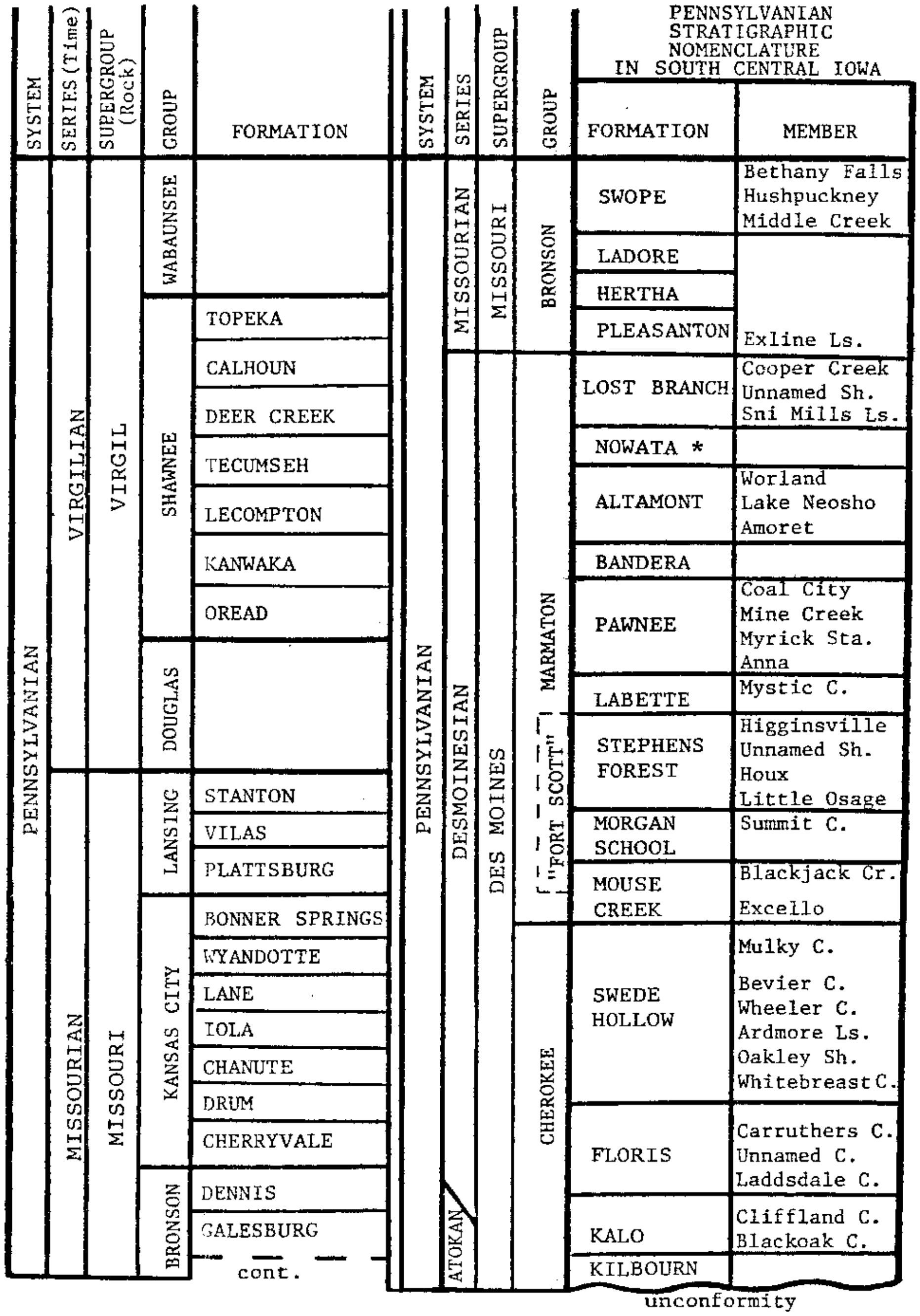

Figure 1-1. Stratigraphic nomenclature of Pennsylvanian strata in Iowa (from Swade, 1985).

Floris Formation

The oldest Pennsylvanian strata exposed at the emergency spillway comprise the upper portion of the Floris Formation. Floris Fm. deposits are exposed in two sections south of the access road and in the section north of the access road. For convenience, the strata will be discussed with respect to their location north and south of the access road.

South of the Road. Two sections are exposed south of the access road. The lowermost exposed Pennsylvanian strata are present at the section located approximately 90 m (300 ft) south of the access road. Only 1.4 m (4.5 ft) of strata are exposed here. The lowermost unit is a 0.1 m (0.3 ft) thick, bioturbated, dolomitic limestone with a few solitary corals and brachiopods. It resembles other limestones which occur at about this position in the middle of the Floris Formation at other localities. Overlying this limestone is approximately 0.6 m (2 ft) of silty, gray-green shale that contains dark red mottles. Between this section and the main section just south of the access road, approximately 0.8 m (2.5 ft) of strata are covered. The covered strata appear to be a continuation of the silty gray-green shale.

At the main section just south of the access road, the lowermost strata include 5.6 m (18.5 ft) of silty gray-green shale that appears to be the same unit as the uppermost strata exposed downvalley. Here the shale is also mottled dark red, and the lower half of the unit contains bands of maroon concretions. A hard, erosionally-resistant, 25 cm (10 inch) thick calcite-cemented siltstone is present near the base of the exposure (Fig. 1-2). Near the top of the unit are scattered septarian concretions varying from 0.1 to 0.3 m (0.3 to 1 ft) in diameter.

The silty, gray-green shale grades upward to a rooted mudstone which forms the seatrock of the Carruthers Coal. Here the coal is 0.1 m (0.3 ft) thick, very pyritic, and contains abundant fusain, a coal lithotype that is fibrous, friable, and has a silky luster. This coal is overlain by a lenticular to nodular argillaceous limestone, 0.15 m (0.5 ft) thick, containing the brachiopods *Desmoinesia muricata, Composita subtilita,* ambocoeliid, and crinoid debris. The limestone is in turn overlain by 1.8 m (6 ft) of calcareous, dark gray shale (6.0 ft) which is fossiliferous in the lower few centimeters.

North of the Access Road. The Floris Formation sequence continues upward across the access road to the north. A coal streak, also assigned to the Carruthers Coal Member, rests on 0.2 m (0.7 ft) of rooted, silty mudstone. Overlying the coal streak is a thin, irregular, calcareous siltstone.

The siltstone is followed upward by 3.7 m (12.1 ft) of light gray shale which becomes increasingly silty upward. This siltstone includes common, small, calcareous nodules. Zones of abundant pyrite occur near the middle of the unit. The upper portion is erosionally resistant and forms a prominent, irregular bench.

At the top of the Floris Formation is a gray shale, 0.9 m (3.0 ft) thick, with common root traces that forms the seatrock of the Whitebreast Coal of the overlying Swede Hollow Formation.

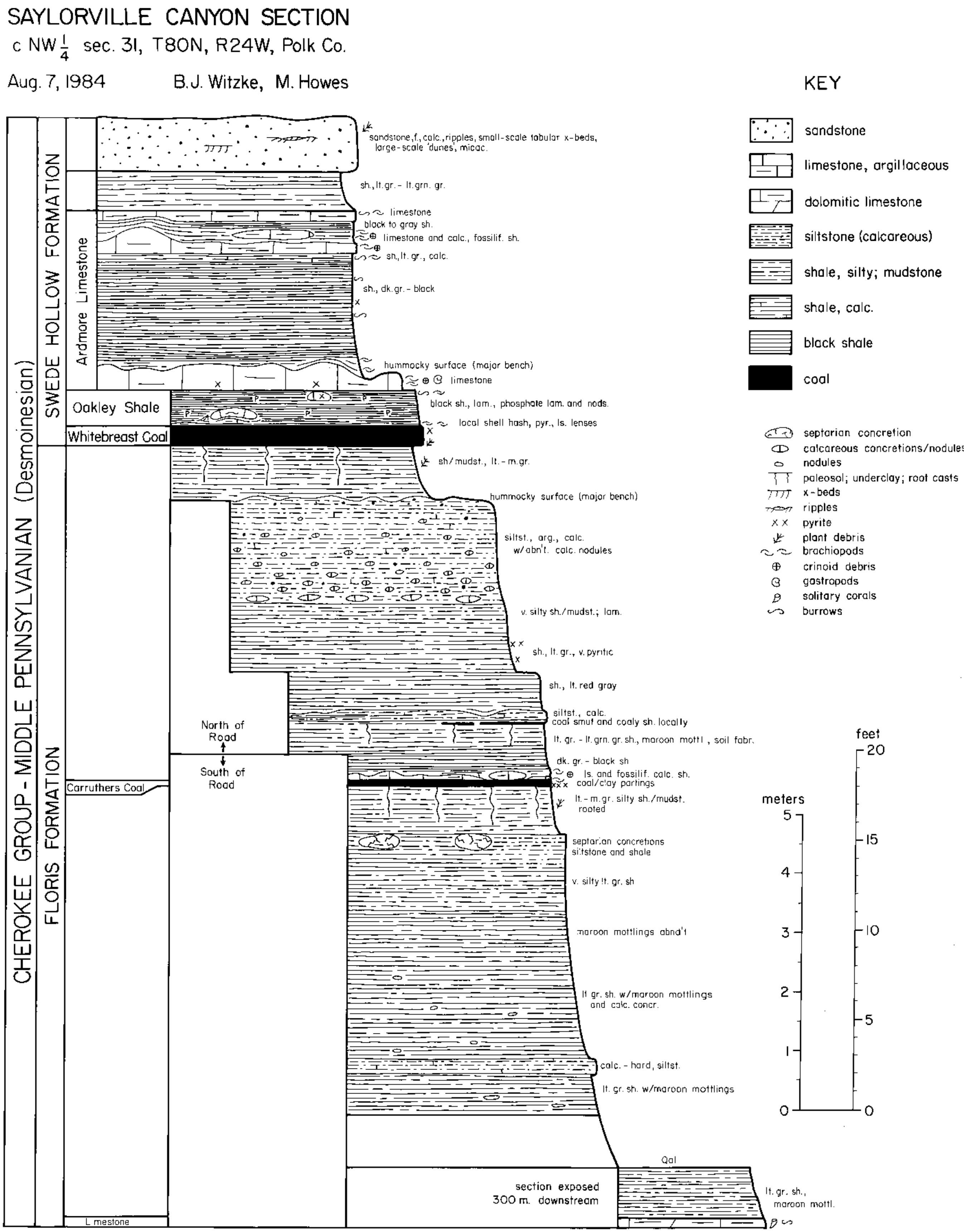

Figure 1-2. Stratigraphic sequence of Pennsylvanian deposits, Saylorville Canyon.

Swede Hollow Formation (Lower Part)

Strata of the Swede Hollow Formation are only exposed north of the access road. The base of the formation is marked by the Whitebreast Coal, which here is 0.25 m (0.8 ft) thick. It is typically uniform over large areas and ranges up to approximately 0.5 m (1.5 ft) thick. Although the Des Moines area has been extensively mined, the Whitebreast Coal has not been exploited in this area. Instead deeper coals, such as the Laddsdale Member of the Floris Formation or coals of the underlying Kalo Formation (see Fig. 1-1), were mined. The Whitebreast Coal, however, has been mined in other areas of the State where it reaches thicknesses up to 0.5 m (1.5 ft).

The Whitebreast Coal is overlain by the Oakley Shale Member, which is a black, fissile shale 0.6 m (1.8 ft) thick. Locally, at the contact between the coal and shale is either a pyritic "shell hash" with abundant productid brachiopods or irregular limestone nodules and concretions. The lower part of the black shale is finely interlaminated with phosphorite. The phosphorite laminae become sparser upward, and small phosphatic nodules occur scattered in the upper part. Rare calcareous nodules occur near the upper contact of the unit. The top 8 cm (3 inches) of the Oakley Shale Member changes from black to dark gray and contains burrow mottles as well as brachiopods, including productids. The upper contact is sharp and fairly planar.

The Oakley Shale Member is overlain by the Ardmore Limestone Member which typically consists of several limestone beds separated by shales. The sequence exposed at the emergency spillway is typical of that found for the Ardmore Limestone Member across the State. The lowermost limestone bed varies from 0.05 to 0.5 m (0.2 to 1.7 ft) in thickness. It is hard, fine grained, argillaceous and fossiliferous. Fossils include brachiopods (*Desmoinesa muricata*, other productids, *Derbyia crassa, Composita subtilita, Mesolobus mesolobus*), scattered crinoid debris, and gastropods. Pyrite-lined fractures and rinds are common, especially near the base. The upper contact is very irregular (hummocky), and locally appears to be nodular. It is overlain by 1.8 m (5.8 ft) of dark gray to nearly black shale that has common to abundant brachiopods (mostly *Desmoinesia*) in the lower few centimeters. Burrowed zones, commonly pyritized, occur throughout the shale, but are especially apparent near the upper contact. The shale is weakly laminated in the upper half, and becomes fossiliferous and very calcareous at the top. Overlying the shale is the upper limestone unit which consists of two to three thin, slightly shaley, irregular limestone beds which vary in thickness from 0.05 to 0.5 m (0.2 to 1.7 ft), interbedded with light to dark gray, calcareous shales. The lower half of this limestone-bearing interval is extremely fossiliferous, and loose brachiopod valves can be picked in profusion from the weathering shales. Noteworthy brachipods include productids (*Desmoinesia muricata*), strophomenids (*Derbyia crassa*), and athyrids (*Composita subtilita*). Scattered crinoid debris is also present. The uppermost limestone bed of the Ardmore Member is only sparsely fossiliferous, with productids and burrows noted. Occurring beneath this upper limestone bed is 0.15 m (0.5 ft) of shale which varies in color from medium gray to black and contains scattered phosphatic nodules.

The Ardmore Limestone Member is overlain by 0.7 m (2.2 ft) of gray-green silty shale which is in turn overlain by approximately 1 m (3.1 ft) of sandstone. The shale-sandstone contact is abrupt and fairly planar, and there is little variation in the shale thickness across the outcrop. The sandstone is fine-grained, calcareous, and includes ripple-drift cross-lamination and cross-bedding. In one area, the top of the sandstone is marked by dunes with superimposed ripples. The sandstone is very resistant to erosion and forms a large bench around the top of the exposure. It also contains common plant fossils, some quite large. Unfortunately, many of these were removed by collectors almost immediately after the exposure was formed so that only the molds are now visible. Log casts of *Lepidodendron* and *Sigillaria* were noted. This sandstone is the uppermost Pennsylvanian unit exposed at the emergency spillway.

Interpretation

The Floris Formation at the emergency spillway is dominated by nonmarine deposits. The thin marine limestone at the base of the outcrop probably originated during a brief incursion of marine water into an otherwise nonmarine environment. The fine, clastic, nonfossiliferous gray-green shale typical of the middle Floris Formation is attributed to deposition in a fluvial-deltaic environment. The overlying coals formed from peat which accumulated in swamps during a rise in base level. The Carruthers Coal is laterally persistent, but can be quite variable in thickness and character. The abundance of fusain in the Carruthers Coal as well as the dark red mottling in the underlying shale suggest partial secondary oxidation. A transitional zone between upper and lower delta plains has been suggested as an environment where such partial oxidation could occur through a minor influx of oxygen-bearing water into the swamp (Horne et al., 1979).

The thin limestone and fossiliferous shale overlying the Carruthers Coal record a brief inundation of the area by marine water as local base level continued to rise. A return to fluvial-deltaic conditions and lower local base level is indicated by the overlying non-marine shales and the coal streak, which is also assigned to the Carruthers Coal Member.

The shale overlying the coal streak becomes increasingly silty upward and contains calcareous nodules suggesting a single cycle of deposition, perhaps from a crevasse splay. In general, this portion of the Floris Formation records the end of the extensive channelization characteristic of the Floris Formation. The thick sandstone bodies in the Cherokee Group strata in Iowa (e.g. along Red Rock Lake and at Ledges State Park) probably are associated with the Floris Formation. At some localities farther to the south the upper Floris Fm. records a shift to more marine-influenced deposition.

The lower portion of the Swede Hollow Formation contains strata similar to the marine-dominated portion of the younger Marmaton Group and Missouri Supergroup strata. These strata bear a strong resemblance to the Pennsylvanian cyclothems described in Illinois (Ravn et al., 1984).

The Whitebreast Coal was deposited on a broad, relatively stable shelf with very little apparent relief. A slow rise in the water table, in response to a eustatic rise in base level, resulted in the accumulation of peat in swamps. Subsequent inundation of the swamps by marine water destroyed the vegetation and terminated peat accumulation.

The Oakley Shale Member, a fissile, black, phosphatic shale, is identical to younger Pennsylvanian "core" shales such as those described by Heckel (1977). The shale and phosphorite nodules were deposited when water depth was sufficient for establishment of a thermocline. Below the thermocline oxygen in the water was consumed by bacterial activity, setting up reducing conditions which facilitated the accumulation of phosphorite. The "shell hash" and limestone nodules at the base of the shale record deepening marine water before the thermocline and reducing conditions were established. These strata are analogous to the "transgressive limestones" of younger Pennsylvanian cyclothems in the Midcontinent.

The Ardmore Limestone Member was deposited following the breakup of stratification in the marine water. During accumulation of the lower limestone bed of the Ardmore, open circulation allowed a marine biota to colonize the area. The overlying dark gray shale exhibits burrowed zones and contains a sparse fauna of low diversity. This interval has been interpreted by Ravn et al. (1984) as rapid prodeltaic influx with declining water depth. The extensive burrowing at the upper contact of the shale probably occurred when the influx of clastic sediment ceased. The uppermost limestone was deposited during a brief stabilization of sea level or a minor transgression. This limestone is typically split into two or more beds by prodeltaic clastic pulses. Additional biostratigraphic and depositional aspects of the Oakley-Ardmore interval are discussed by Swade (1985).

The Ardmore Limestone Member is overlain by a non-marine shale and sandstone deposited after withdrawal of the sea. The near absence of scouring at the base of the sandstone suggests a distributary mouth bar origin.

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PART 2. THE QUATERNARY DEPOSITS OF THE SAYLORVILLE EMERGENCY SPILLWAY

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Iowa Geological Survey

Objectives

Field trip participants viewing the Quaternary deposits in the Saylorville Emergency Spillway should closely examine the unique exposures and stratigraphic relationships of this Quaternary sequence. Items to note include:

1. Deposit geometry; the lateral occurrence of several stratigraphic units in the emergency spillway exposures means that cross-cutting stratigraphic relationships must be evaluated besides the usual vertical superposition relationships.

2. Nature of the preserved sequence; unlike the regional Quaternary sequence, the emergency spillway sequence preserves extensive late-Wisconsinan and pre-Wisconsinan alluvial deposits. The emergency spillway exposures thus provide a rare opportunity to observe and study the nature of older Quaternary alluvial deposits and learn something about their paleoenvironments.

3. Genetic differentiation of Quaternary deposits; the emergency spillway sequence includes deposits of glacial, glaciofluvial, eolian, alluvial, and colluvial origin. We will discuss the primary sedimentologic properties and facies relationships required to genetically differentiate these different deposits.

4. Time-stratigraphic placement of the Quaternary deposits; the Quaternary sequence exposed in the emergency spillway channel includes five stratigraphic units which span the time from the Holocene to the pre-Wisconsinan. We will discuss the techniques used to time-stratigraphically subdivide this sequence, including analysis of stratigraphic relationships (cross-cutting and vertical superposition relationships) and secondary (diagenetic and pedogenic) properties of the deposits.

5. Several companion papers will focus on specialized aspects of the Quaternary sequence. Dr. R.G. Baker will comment upon paleoenvironmental interpretations that can be made from pollen and plant macrofossils in the late Wisconsinan-age alluvium, while Dr. T. J. Frest will comment on paleoenvironmental interpretations that can be made from mollusc (snail) fossils present in the late Wisconsinan-age loess and alluvium. Dr. G.R. Hallberg will discuss the influence of

local source rocks (the Pennsylvanian-age strata) on the clay mineralogy of the Quaternary sequence.

6. Remaining interpretive problems; during the course of the field trip we would also like to comment on remaining problems in interpreting the Quaternary sequence through time:

   a. What was the paleogeography of the site through time?
   b. What were the detailed depositional environments for some of the stratigraphic units, particularly the fine-grained alluvium, and the glacigenic diamictons.

Overview of the Quaternary Deposits

The Saylorville Emergency Spillway occurs along the western margin of the present Des Moines River valley. Natural valley incision and artificial grading of the original emergency spillway channel have progressively truncated portions of the Quaternary sequence, exhuming older Quaternary deposits and Pennsylvanian-age bedrock. At present, the Quaternary deposits occupy a buried bedrock valley which is cut successively through the Pennsylvanian-age Swede Hollow and Floris Formations. This bedrock valley includes roughly the lower one-half of the emergency spillway channel shown on Figure 2-1.

Five different Quaternary stratigraphic units occur in the emergency spillway exposures, from youngest to oldest: 1) Holocene-age alluvium and colluvium; 2) late Wisconsinan-age glacigenic deposits (Des Moines Lobe deposits); 3) late Wisconsinan-age alluvium; 4) late Wisconsinan-age loess; and 5) pre-Wisconsinan age alluvium. Three of these five stratigraphic units, the Holocene-age alluvium and colluvium, late Wisconsinan-age glacigenic deposits (Des Moines Lobe deposits), and pre-Wisconsinan age alluvium, are each comprised of multiple fills or deposit types.

There are a number of unusual aspects to the Quaternary sequence in the Saylorville Emergency Spillway. First, the geometry of the stratigraphic units is not the typical 'pancake layer' stratigraphy where simple vertical superposition relationships can be used to determine the relative age of the different stratigraphic units. Instead, many of the stratigraphic units lie lateral to one another, and cross-cutting relationships must be analyzed to determine relative age.

Secondly, the Quaternary sequence in the emergency spillway is a sequence dominated by alluvial fills, rather than the more typically preserved upland sequences (compare the Quaternary sequence preserved here with the Acorn Valley Section, Stop 2, described in Part 6). The pre-Wisconsinan and Wisconsinan-age alluvial fills are hardly ever encountered (preserved) in stratigraphic sections across the state.

Thirdly, the pre-Wisconsinan age alluvial fills are dominated by fine-grained, and in some cases, poorly-sorted deposits which can at times be difficult to distinguish from loess or glacial till. In such cases analysis of primary sedimentary properties and lateral facies relationships is essential for the correct identification of the deposits' origin.

Finally, time-stratigraphic classification of the deposits (as Holocene, Wisconsinan, pre-Wisconsinan) can be made here *in lieu* of radiocarbon dates if stratigraphic relationships (superposition, cut-and-fill relationships) and

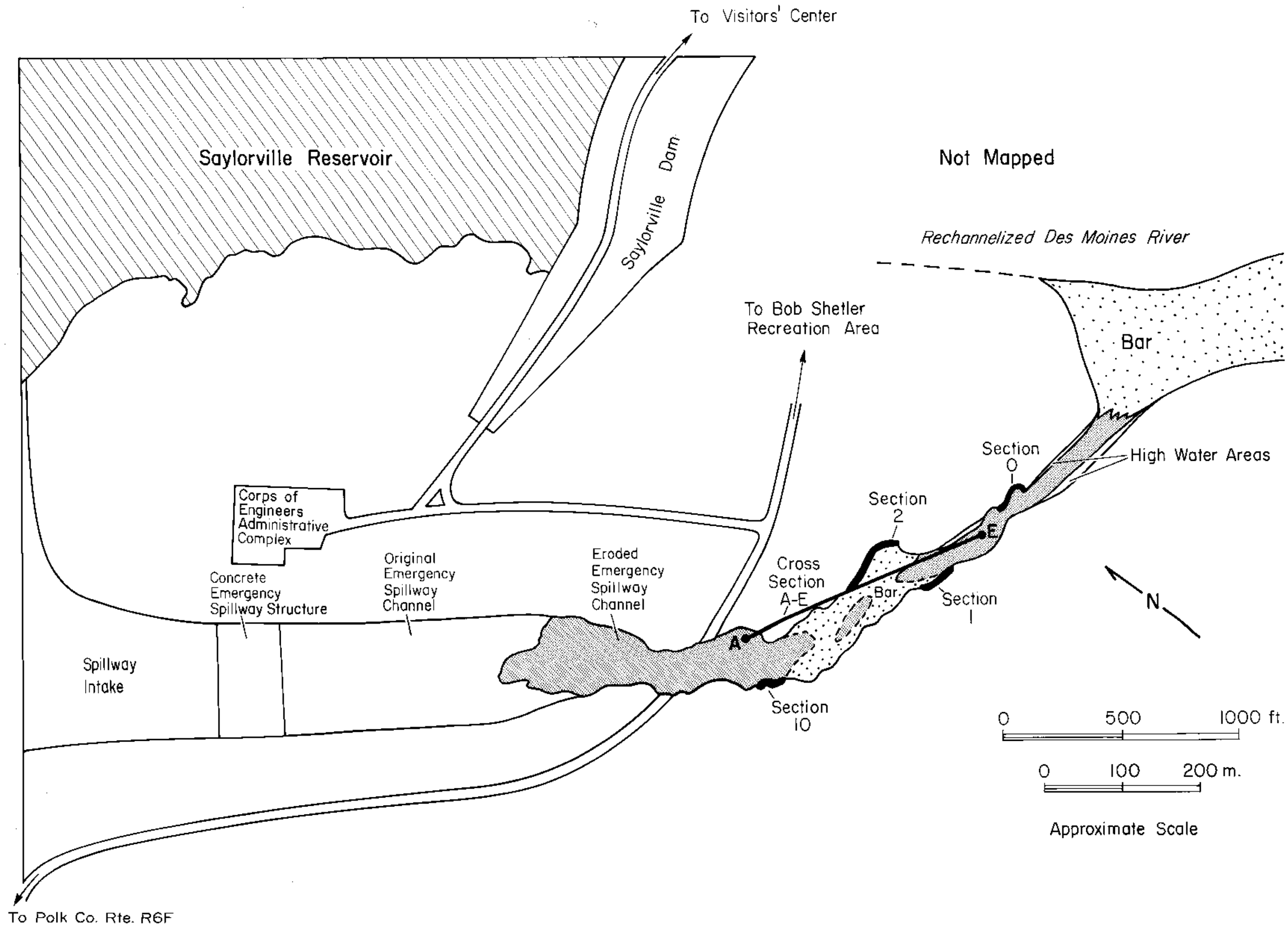


Figure 2-1. Sketch map of the Saylorville Emergency Spillway area.

secondary properties (soil and weathering-related properties) are analyzed.

To study the extensive Saylorville Emergency Spillway exposures, the channel walls on both sides of the spillway were examined. Representative sections were drawn, the sections were described, and vertical profiles were sampled for standard particle-size and clay mineralogic data (Hallberg, ed., 1978). It should be noted that this sampling was reconnaissance sampling in which the purpose was to provide a gross characterization of the strata present; more rigorous sampling and description for detailed sedimentologic studies could still be done. Table 2-1 and the following sections summarize the properties of the various Quaternary stratigraphic units exposed in the emergency spillway exposures.

Quaternary Strata in the Emergency Spillway

Holocene Alluvium and Colluvium

General. Pre-Saylorville Late Holocene alluvium is exposed along the northeastern wall (left bank) of the emergency spillway channel (Figure 2-2, cross-sections A-D). The Holocene alluvium and colluvium consists of thin, reworked sediments (colluvium or pedisediment) on hillslopes (some of these are now paleohillslopes, buried by fill placed during construction of the original emergency spillway channel) which descend into low-order drainageways that occur (or occurred) on the modern land surface. Alluvial fills in these low-order drainageways may consist entirely of fine-grained alluvial fills or of fining-upward sequences composed of basal sands or gravels overlain by fine-grained alluvium. Some drainageways contain multiple fill units. Section 2 (Fig. 2-3) shows many of the characteristic features of the Holocene alluvium and colluvium in the emergency spillway exposures. Profile 2A (Fig. 2-4 and Appendix 2-1) was sampled and described to characterize some of the multiple Holocene-age alluvial fills in the spillway exposures. The following discussion details properties of the alluvium there. In this area (Section 2) the top of the exposure approximates the original land-surface. At the southeastern edge of Section 2 a wedge of man-made fill composed of abundant clasts of Pennsylvanian rocks in a loamy matrix buries a former small northwest- to southeast-trending tributary to the Des Moines River (Fig. 2-2, cross-section C-D). Prior to grading of the emergency spillway area this tributary ran transversely across what is now the emergency spillway and extended northwestward at the location where the access road (Fig. 2-1) crosses the emergency spillway today.

The pre-dam Holocene alluvium occurs as a wedge of deposits paralleling the former tributary course. The Holocene alluvium rests unconformably on Pre-Wisconsinan alluvium on the north end of Section 2 and on Wisconsinan loess in the central and southern portions of this area (Figure 2-3).

Although no datable material was recovered from the upper alluvial deposits at this section, two lines of evidence indicate that the alluvium is Holocene in age: 1) the superposition of the alluvium on the Wisconsinan-age loess indicates that the alluvium is younger than the loess and 2) previous experience with Holocene alluvium in the Des Moines River valley and its tributaries indicates that this alluvium has primary and secondary features comparable to Holocene alluvium in the area. These properties are discussed below.

Table 2-1. Summary of properties of Quaternary stratigraphic units exposed at the Saylorville Emergency Spillway.

STRATIGRAPHIC UNIT	PRIMARY PROPERTIES texture	bedding structures	GEOMETRY	CARBONATE CONTENT	SECONDARY PROPERTIES Pedogenic (soil) features	Weathering zone features	Jointing
HOLOCENE ALLUVIUM AND COLLUVIUM	1. Fine-grained sediments range from silt loam to sandy loam 2. Basal channel fills consist of bedded sands and pebbly gravels	1. Weak to continuous stone line at base. 2. Faint stratification at base grading upward to massive fine-grained sediments. Thinnly-bedded sands and pebbly gravels at base of low-order drainage channels with finer-grained sediments at top.	Unconformably overlies older deposits forming low-order modern drainageways; in drainageway this unit may consist of multiple fills, indicating punctuated erosion and filling during the Holocene; upper surface disturbed by clearing and grading in many areas.	Non-calcareous	Modern soil profile developed in top: 1. Systematic soil horizonation with depth (A-E-B-C or A-B-C horizons). 2. Organic matter accumulation--development of A horizon. 3. Development of secondary soil structure. 4. Development of discontinuous cutans--secondary clay coatings--in B horizon. 5. Buried soil evident in some areas.	Where the sediments are thicker than the modern soil, reduced and mottled reduced, grayish colors predominate.	Absent
WISCONSINAN GLACIGENIC DEPOSITS							
1. Main diamicton unit	Variable between sections; section 1: massive, uniform pebbly silt loam diamicton. Section 10, massive, variable pebbly clay loam diamicton. Section 0: pebbly silt loam diamicton with common imbricated block inclusions of loess; a few small-scale channel-fill inclusions.	Massive or with imbricated block inclusions of loess; weakly bimodal pebble fabric with main mode dipping to W-NW in same direction as imbricated block inclusions.	Slightly undulating, irregular lower boundary filling in low areas on the surface of the underlying Wisconsinan loess and alluvium; planar, erosional contact where it overlies associated glaciofluvial sands and fine gravels; upper surface truncated either by Holocene erosion or by grading for the original emergency spillway channel.	Generally calcareous below modern soil profile; leached at Section 10.	Surface truncated; soil horizons absent.	In most sections, unoxidized, unleached; only 1 to 2 ft. (0.3-0.6 m) below trucated surface is there secondary oxidation along numerous, closely-spaced, subhorizontal joints. Section 10 apparently is near the original ground surface, and there mottled oxidized and reduced, leached horizons are present, the weathering apparently enhanced by the decomposition of locally derived, easily-weathered, pyrite-containing Pennsylvanian bedrock.	Occasional, if any, subvertical joints with little or no secondary alteration along them. Upper 1 to 2 ft. (0.3--0.6 m) of truncated sections commonly have numerous closely-spaced sub-horizontal joints which break up into plates 2 cm or less in thickness, and several cm in length.
2. Associated glaciofluvial deposits	Variable from fine sand to pebbly gravel	Irregularly bounded beds of planar-bedded and cross-bedded sands and fine gravel or incised small-scale channel fills.	Where present, unconformable on underlying Wisconsinan alluvium; upper surface is an abrupt planar erosional surface with the overlying diamicton.	Calcareous	Unaffected by soil forming processes.	Unoxidized, unleached, but readily weathers to oxidized upon exposure.	Absent
WISCONSINAN ALLUVIUM	Dominantly fine-grained, silt loam alluvium with thin, discontinuous sand lenses; abundant mollusc shells and fragments of organic matter (wood, twigs, etc.).	Laminated to thinnly-bedded fine-grained sediments with thin (up to 1 cm thick) discontinuous (lenticular), wavy sand lenses.	Base generally covered; at Section 0-D appears to overlie loess. Occurs to south of low-order Holocene drainageway that formerly crossed the emergency spillway area prior to construction; top truncated by construction along part of the spillway, infilled with Des Moines Lobe glacigenic deposits elsewhere.	Calcareous	Unaffected by soil forming processes.	Unoxidized, unleached, but coarser sediments weather to oxidized upon exposure.	Absent
WISCONSINAN LOESS	Fine-grained silt loam; occasional mollusc shells.	Massive.	Overlies Pre-Wisconsinan alluvial fills; at section 2, fills small valley incised into pre-Wisconsinan alluvium.	Section 2: calcareous; common secondary concretions. Section 10: lower portion leached with some organic matter accumulations.	Occurs below modern soil profile.	1. Deoxidized, unleached; reduced at Section 10. 2. Infrequent subvertical joints. 3. few hard, common soft secondary carbonate concretions. 4. common 'pipestems' (secondary iron oxide concretions)	Infrequent sub-vertical joints with secondary oxidation rinds.
PRE-WISCONSINAN ALLUVIUM (multiple alluvial fills and buried soils)	Dominantly fine-grained, poorly sorted loam, silt loam, clay loam, sandy loam alluvium; lag gravels and sand beds commonly mark the base of individual fills; occasional graded, fining upward beds.	Multiple alluvial fills; base of individual fills commonly marked by gravel lags and sand lenses; fine-grained sediments generally massive, poorly sorted, occasionally stratified or fining upward.	Unconformably overlies Pennsylvanian-age bedrock; fills in valley on bedrock surface. Unconformably overlain by Wisconsinan loess, Holocene alluvium, and Wisconsinan till of the Des Moines Lobe at various locations along the emergency spillway channel.	Non-calcareous.	Multiple buried soils within the unit, each developed at the top of one of the alluvial fills; most of the buried soils are truncated. Pedogenic features found among the buried soils include: 1. systematic soil horizonation 2. organic matter accumulation--A horizon development 3. development of secondary soil structure 4. development of thin, discontinuous to thick, continuous cutans--secondary clay coatings in B horizons 5. common secondary iron and manganese oxide coatings and concretions.	1. Below buried soils oxidized and reduced colors present. 2. Secondary, subvertical jointing with common secondary weathering changes. 3. common secondary iron and manganese oxide coatings and concretions (including 'pipestems').	Secondary, sub-vertical joints present; secondary iron oxide staining along joints.

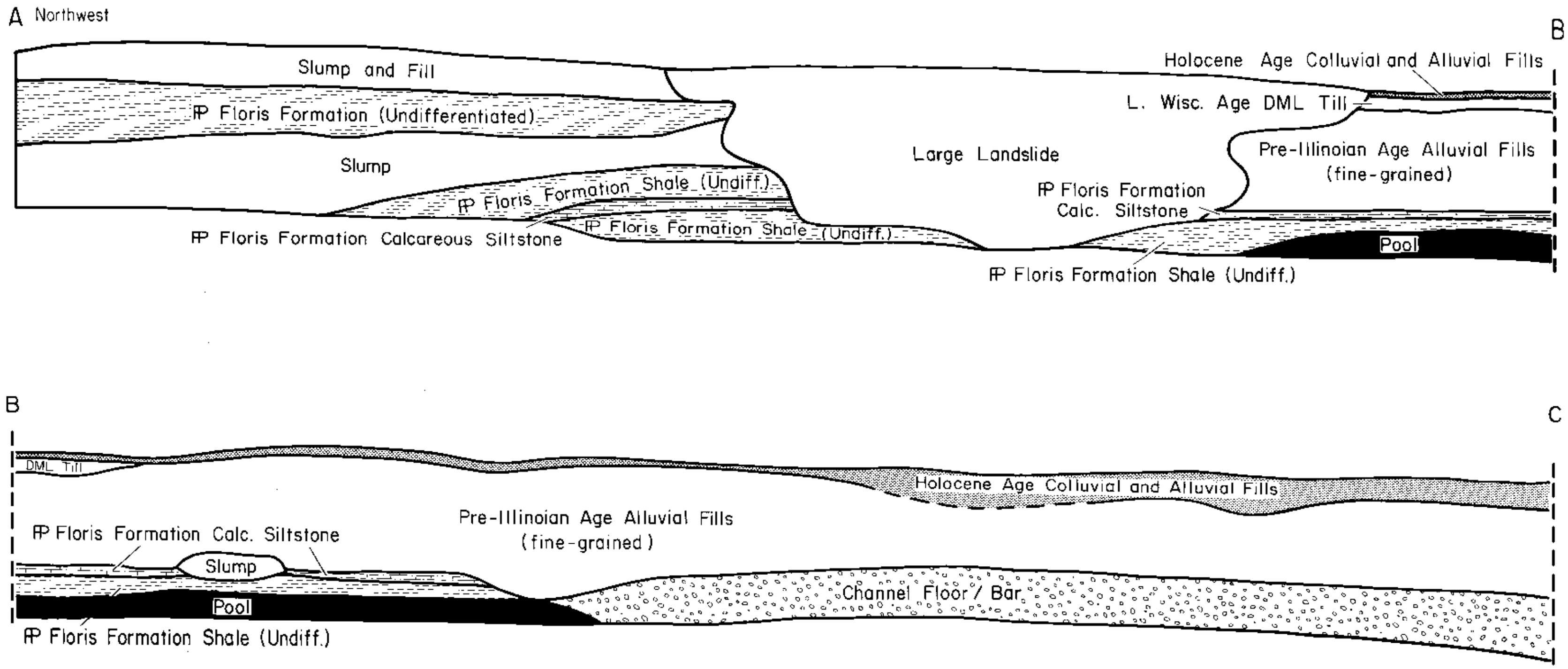


Figure 2-2. Cross-section along the left (northeast) bank of the emergency spillway beginning approximately at the access road (Station A). Redrawn from a photo mosaic.

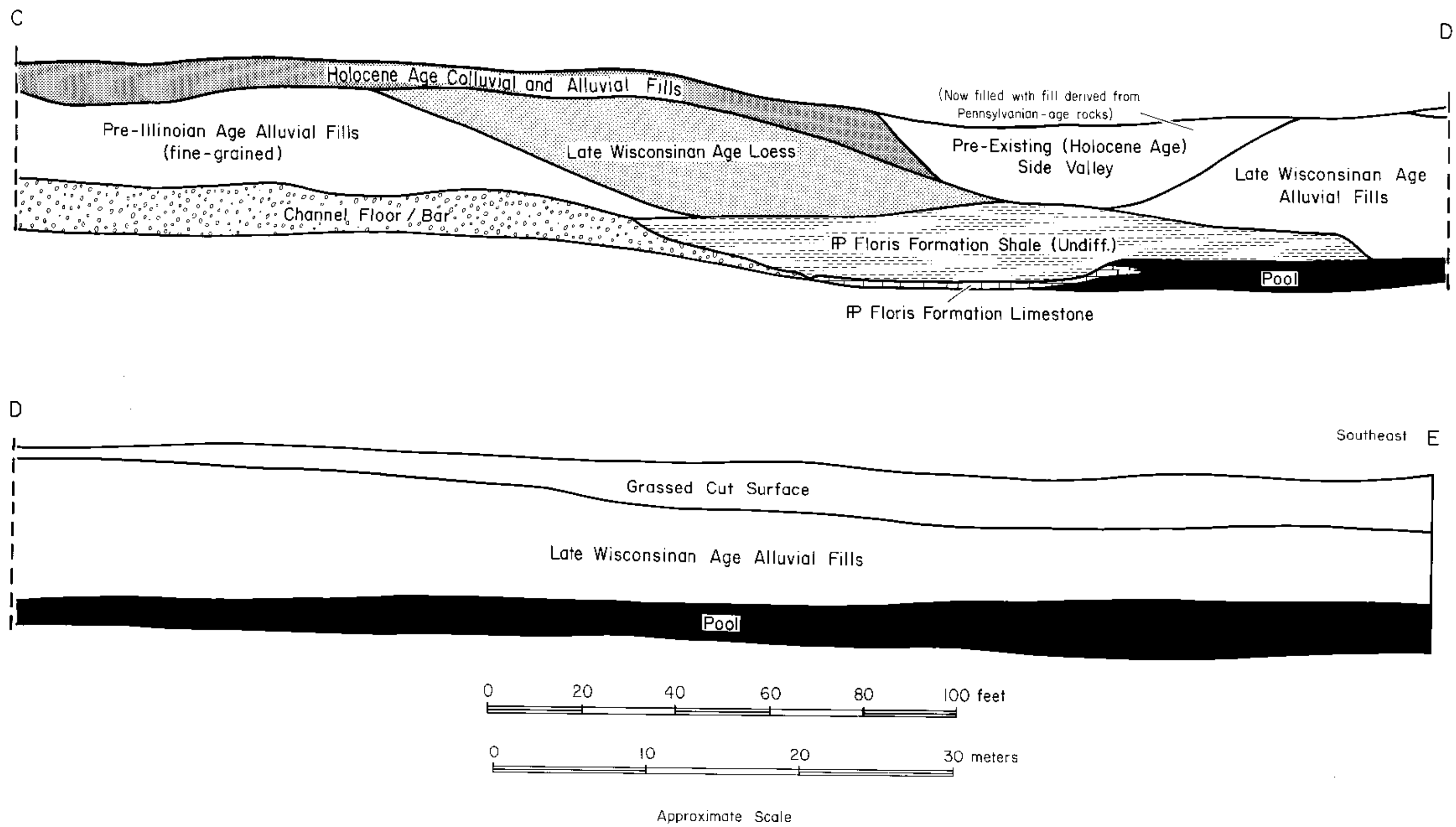


Figure 2-2. Continued.

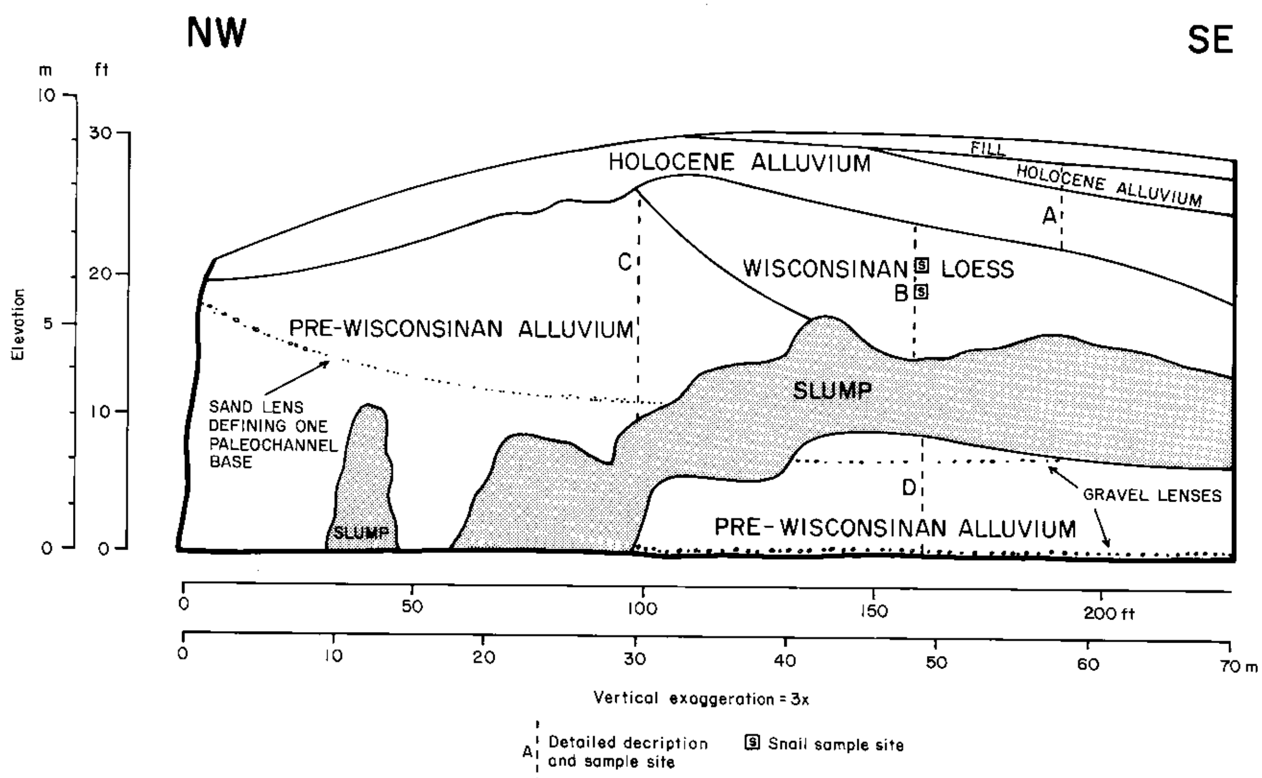


Figure 2-3. Cross-sectional sketch of the generalized stratigraphy at Section 2.

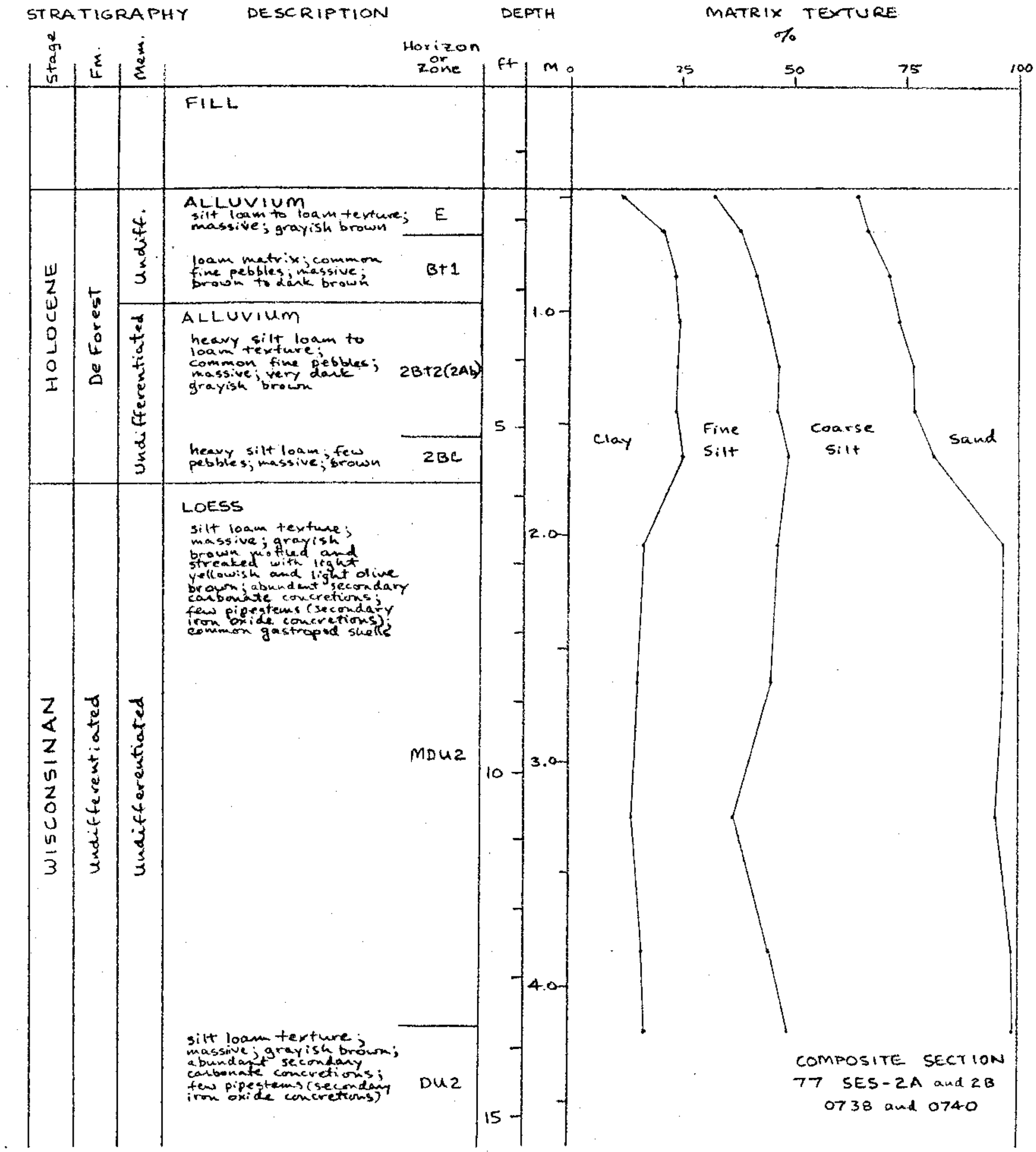


Figure 2-4. Stratigraphy and particle-size of profiles A and B, Section 2. Location of profiles shown on Fig. 2-3.

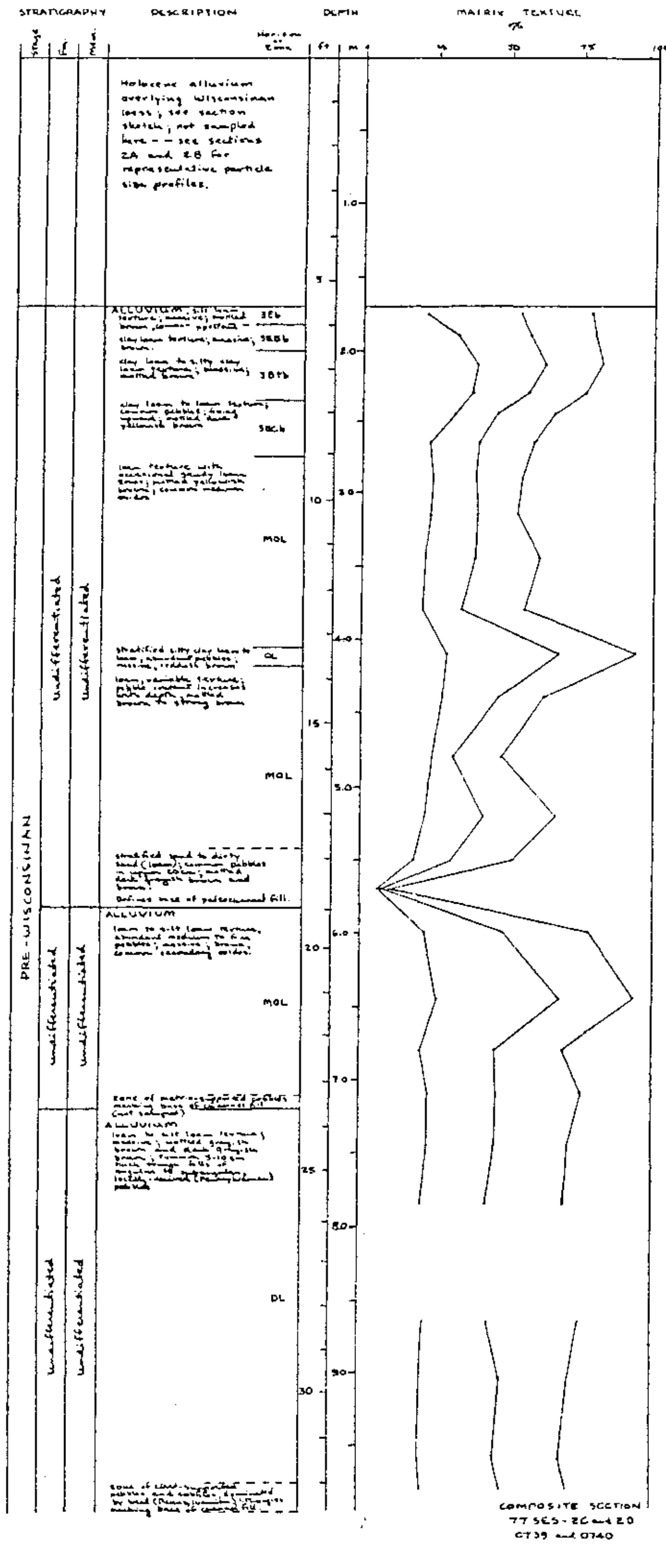


Figure 2-5. Stratigraphy and particle-size of profiles C and D, Section 2. Location of profiles shown on Fig. 2-3.

Primary Properties. Holocene alluvium in Section 2 has been extensively modified by post-depositional pedogenic (soil) processes, and therefore few primary depositional features are evident. The alluvium has a silt loam to loam texture (Fig. 2-4), having originated from erosion of loamy Des Moines Lobe glacial deposits and pre-Wisconsinan alluvium as well as silty late Wisconsinan-age loess. In some places where the Holocene deposits are cut into the pre-Wisconsinan alluvium, a stone line occurs at the base of the Holocene deposits. This stone line is a lag deposit derived from erosion of the older alluvium. In a few parts of the section, the lowermost part of this unit exhibits faint stratification consisting of thinnly-bedded pebbly sands and gravels.

Two distinct Holocene alluvial fills are present at Section 2A (Fig. 2-3). The distinction between the two is easiest to recognize on the basis of secondary alteration features, which will be described below, but the two are also slightly different in texture (particle-size distribution) (Fig. 2-4). The uppermost alluvial unit contains significantly more sand than the underlying unit.

Secondary Properties. Secondary alteration (soil) features have extensively modified the Holocene alluvium in Section 2. All these alterations fall into the category of pedogenic--those associated with soil development. Small valley alluvial units, especially those deposited marginal to a channel, usually accumulate slow enough so that they are influenced by pedogenic (soil) processes during, as well as subsequent to their accumulation (Riecken and Poetsch, 1960). Soils developed in these situations are referred to as 'cumulic' and are characterized by relatively thick soil horizons. In addition, since soil development is occurring during accumulation of the unit, the soil profile tends to "grow upward" and former surface (A) horizons become subsurface (B) horizons as the deposit continues to slowly accumulate. Both these phenomena are evident at Section 2A (see description, Appendix 2-1).

Fourty-six centimeters of fill bury the pre-construction surface at the described section (2A). Underlying the fill, the uppermost Holocene alluvial fill is marked by the secondary development of E and Bt soil horizons (for a general discussion of soil horizon characteristics and nomenclature see Bettis, 1984; Guthrie and Witty, 1982). An E horizon is a soil horizon usually associated with forest vegetation on the landscape, and is a horizon of eluviation in which iron oxides, organic matter and clay are stripped from the soil matrix giving the materials a characteristic grayish brown color and platy secondary soil structure. The stripped iron oxides, clays and organic matter are transported to the underlying B soil horizon where they accumulate as secondary coatings or concretions. The textural analysis of this zone shows that it is depleted in clay relative to the remainder of the alluvium. An E horizon is a subsurface soil horizon that forms beneath darker, relatively organic-rich A or O topsoil horizons. The absence of A or O horizons at this site probably resulted from removal of the upper few centimeters of alluvium prior to or during construction of the original emergency spillway.

An argillic (Bt) soil horizon (a type of secondary clay-enriched B horizon, Soil Survey Staff, 1975) is present beneath the E horizon in the uppermost alluvial fill. This is the zone where clay, iron oxides, and other compounds leached from the overlying horizons accumulate. This horizon has the blocky structure and secondary clay accumulations (cutans) along ped (secondary soil structural units) faces that is characteristic of Bt horizons.

The top of a second Holocene alluvial fill occurs at a depth of 96 cm in profile 2A (Appendix 2-1). The contact between fills is marked by lithologic and pedologic discontinuities. The top of the second alluvial fill has a buried soil developed in it which, in turn, has been modified by later soil-forming processes in the overlying thin alluvial fill. At profile 2A the difference between the upper and lower alluvial fills is marked as the lower alluvium becomes much darker, the soil structure changes for subangular blocky to angular blocky, and the cutans (secondary clay coatings) change from thin and discontinuous to thick and continuous (Appendix 2-1, description 2A). These changes, as well as stratigraphic relations across the outcrop (Fig. 2-3), indicate the presence of a buried soil developed in the lower alluvium. The dark color of this horizon just below the contact suggests that it originally was the A (surface or topsoil) horizon of the soil developed in the basal Holocene alluvial unit prior to burial by the uppermost alluvium. The thickness of the dark horizon suggests that this was an overthickened (cumulic) A horizon and that the soil originally developed under the influence of grass vegetation, a change in vegetation from that influencing soil development in the modern surface soil.

This original soil has been extensively modified by subsequent burial and pedogenesis. As the soil surface was buried, the former A horizon became the Bt horizon of the modern surface soil developing in the thin overlying alluvium. Iron oxides, clay, and other materials moving through the overlying alluvium accumulated in the buried A horizon as a result of a change in porosity and the complexing and flocculating properties of organic matter in the buried A horizon.

Below a depth of 156 cm the lower Holocene alluvium is less altered pedogenically than above. Several pedologic features such as cutans and soil structure are still discernable however. This zone is the lower portion of the buried solum and the place where the few remaining primary features in the Holocene alluvium can be observed. The colors of the Holocene alluvium in this section indicate that the soils here are well-drained. The iron compounds in these deposits are oxidized. Mottles within the buried A horizon indicate that at times in the past this zone became saturated for short intervals, allowing free iron in the deposits to migrate to areas where it accumulated as mottles. The change in porosity and soil structure from the overlying Bt1 horizon to the buried A horizon (2Ab) may have been sufficient to promote saturation of the 2Ab horizon.

Depositional Environments. Several properties of the Holocene alluvium at this site give us insights about its environment of deposition. The pebble lag or sandier zone at the base of the unit indicates an erosional episode preceeded deposition of the rest of the unit. The general lack of bedding features and the thinness of the unit suggest that this alluvium was deposited marginal to a channel, probably near the edge of the valley. The buried soil, as well as the properties of the surface soil indicate that alluvium accumulated episodically. All these features are consistent with the interpretation that this is alluvium associated with a small tributary valley. The alluvium probably accumulated in the footslope or toeslope position at the base of the former valley slope.

The oxidized colors of the deposits and the presence of an argillic soil horizon indicate that the alluvial deposits are early to middle Holocene in age. These properties are characteristic of alluvium of this age in the Midwest (Bettis, 1983). Dry conditions and resultant lowered water tables during the middle Holocene promoted oxidation of alluvial deposits throughout the region.

Late Wisconsinan-Age Glacigenic Deposits (Des Moines Lobe deposits)

General. The Saylorville Emergency Spillway is located a scant 9 miles (15 km) north of the southern terminus of the Des Moines Lobe of the Wisconsinan-age Laurentide ice sheet. Because of the plethora of radiocarbon dates from the base of the Des Moines Lobe in this immediate vicinity (Ruhe, 1969; Kemmis et al., 1981), no wood from the Des Moines Lobe basal till was submitted for radiocarbon dating. Dates from the area consistently range around 14,000 RCYBP.

It appears Quaternary glaciers in much of the Midwest carved a flat bed on easily eroded substrate materials (such as older Quaternary deposits) by eroding off subglacial highs and filling in subglacial lows. Thin ice and a comparatively short time for ice occupation led to the inability of the Des Moines Lobe ice to erode a flat bed in the Saylorville area. The result is greater local relief on the sub-Des Moines Lobe surface than farther to the north. This greater local relief on the sub-Des Moines Lobe surface can be seen, on the small scale, in the emergency spillway exposures where Des Moines Lobe deposits are locally preserved in broad, shallow lows on the top of older Quaternary deposits (Section 0, Fig. 2-6; Section 1, Fig. 2-12; Fig. 2-2, cross-sections A-C).

Truncation of the surface of the Des Moines Lobe deposits resulted both from subaerial erosion as the Des Moines River valley periodically downcut and from grading during construction of the original emergency spillway. Comparing elevations of adjacent divides on both the east and west sides of the valley surrounding the emergency spillway suggests that on the order of 15 to 20 m (50 to 60 ft) of Des Moines Lobe deposits have been removed.

The Des Moines Lobe deposits present in the Saylorville Emergency Spillway are variable. The bulk of the deposits are diamictons; that is, poorly-sorted, pebbly silt loam, clay loam, and loam (Fig. 2-15A). These diamictons vary in composition and character between the locations where they are exposed in the spillway (Figs. 2-7, 2-8, 2-14, and 2-16; and Appendix 2-1). However, the various sedimentologic properties of the diamictons exposed in the emergency spillway all suggest that the diamictons were deposited subglacially. The diamictons are thus interpreted to be 'basal tills,' following the terminology of Dreimanis (1976).

The Des Moines Lobe deposits also include thin glaciofluvial deposits which occur beneath the basal tills at Section 0 (Fig. 2-6) and Section 1 (Fig. 2-12). The following sections describe the properties and depositional environments of these various late Wisconsinan-age Des Moines Lobe deposits.

Primary and Secondary Properties: Diamicton deposits. The Des Moines Lobe diamicton deposits still remaining in the emergency spillway exposures are thin, ranging from 1.75 to 3 m (5 to 10 ft) in thickness. Basal tills of the Des Moines Lobe are generally massive and uniform in composition (Kemmis et al., 1981), whereas those exposed in the emergency spillway are highly variable in nature, and will be discussed section by section.

Section 1B (Figs. 2-12, 2-14; Appendix 2-1) is the simplest section, and resembles "typical" Des Moines Lobe basal till. Except for the upper half meter (1 to 2 ft), the Des Moines Lobe diamicton is a classic matrix-dominated diamicton: a massive, poorly-sorted, non-stratified deposit in which various sized pebbles are individually inset in a fine-grained silt loam matrix. This massive diamicton, like massive basal tills from many other portions of the Des Moines Lobe (Kemmis et al., 1981), has extremely uniform

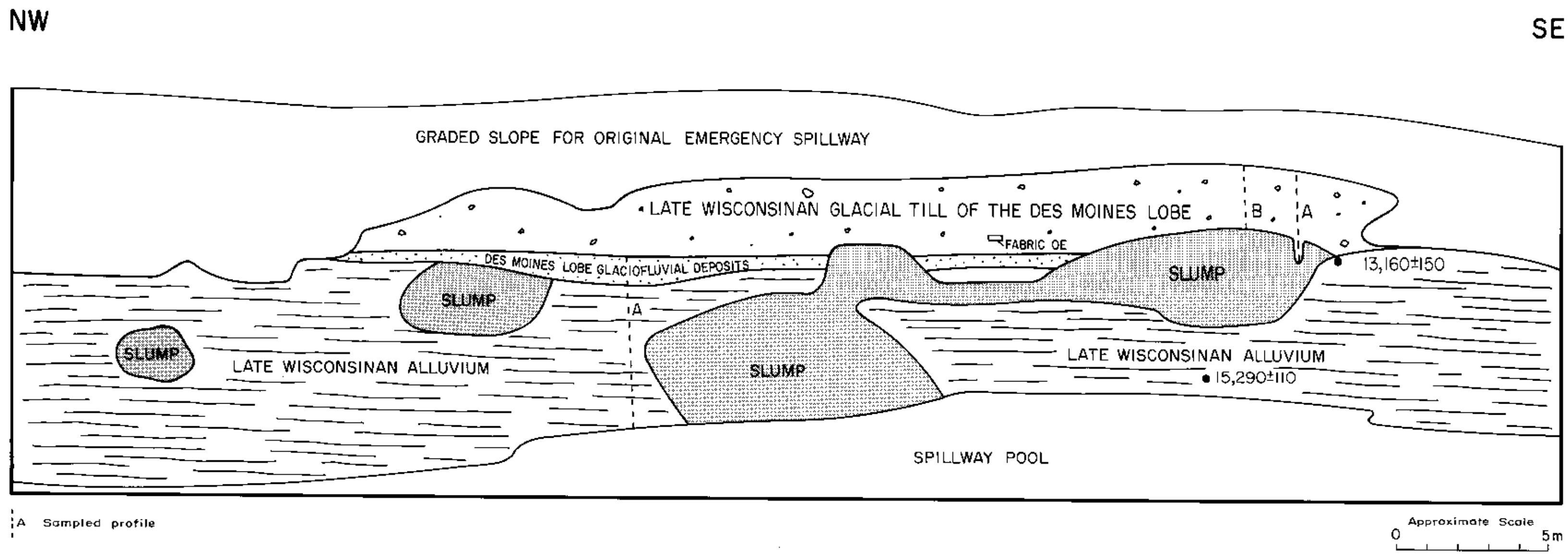


Figure 2-6. Cross-sectional sketch of the generalized stratigraphy exposed at Section O. Redrawn from a photo mosaic.

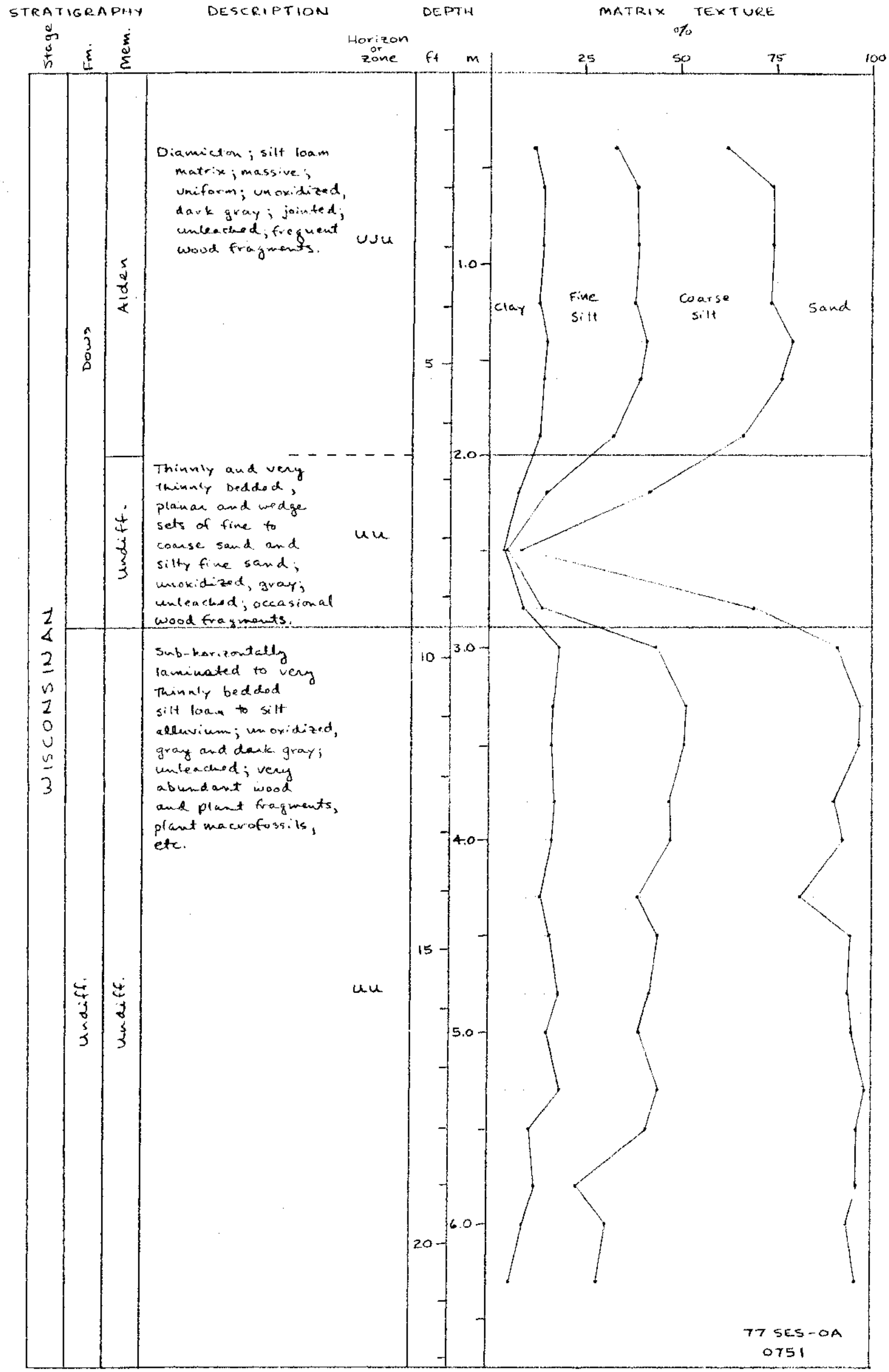


Figure 2-7. Stratigraphy and particle-size of profile A, Section O. Profile location shown on Fig. 2-6.

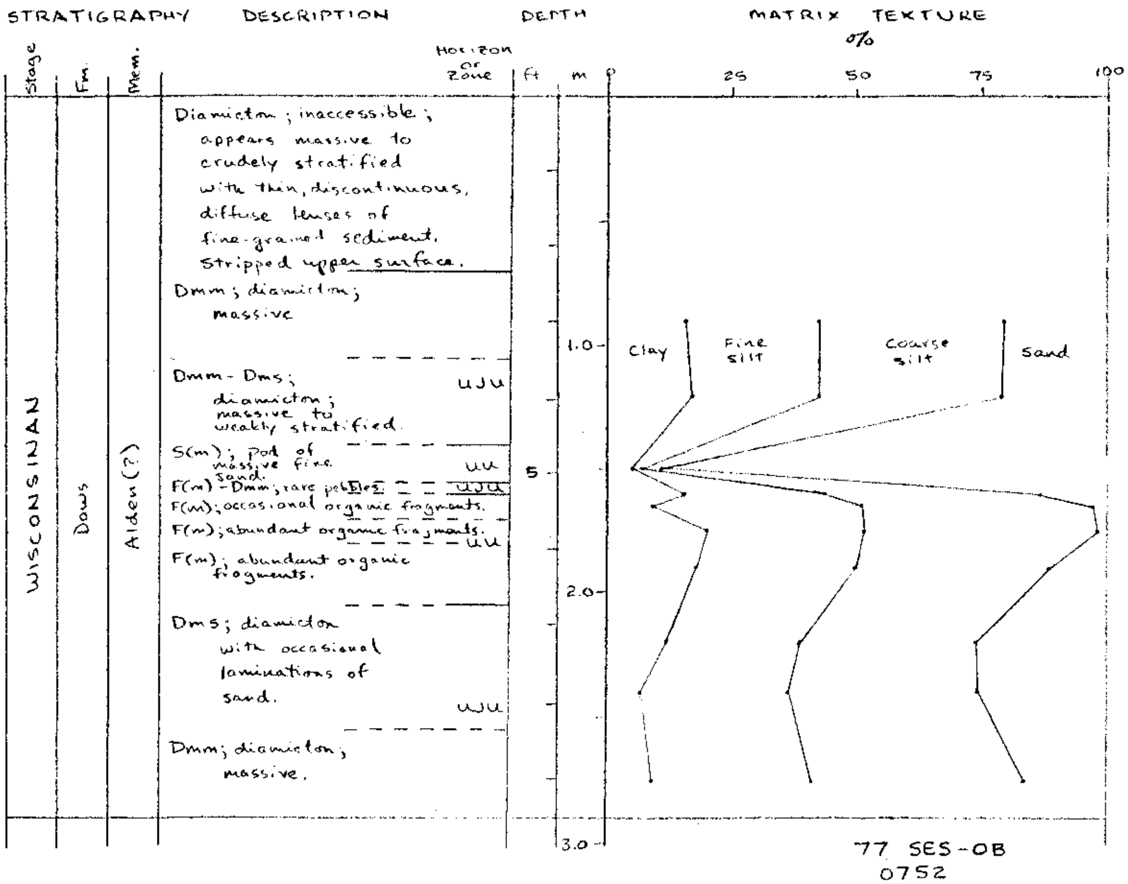


Figure 2-8. Stratigraphy and particle-size of profile B, Section O. Profile location shown on Fig. 2-6.

matrix texture (Fig. 2-14). This diamicton is considerably lower in sand content than is typical for basal tills of the Des Moines Lobe (Kemmis et al., 1981). This lower sand content, with a corresponding increase in silt content, is likely the result of the Des Moines Lobe incorporating the local Wisconsinan-age loess substrate and mixing it in with farther-traveled debris. Kemmis and Lutenegger (unpublished) have found a systematic increase in silt content southward (and corresponding decrease in sand content) in massive Des Moines Lobe basal tills near the southern terminus of the Des Moines Lobe. From Ames south, Wisconsinan-age loess becomes the dominant substrate material beneath the Des Moines Lobe deposits. The massive Des Moines Lobe diamicton at Section 1B is unweathered: unoxidized (dark gray), unjointed (massive) and unleached. No secondary oxidation or various concretions or coatings occur. Wood fragments are common throughout the diamicton. The diamicton has an undeformed, planar, erosional lower contact with late Wisconsinan-age alluvium or channel fills of glaciofluvial deposits incised into the late Wisconsinan-age alluvium (Fig. 2-12).

The upper half meter (1 to 2 ft) at Section O is also a diamicton, but it is extensively jointed with sub-horizontal joints spaced at 1 to 3 cm intervals (1/3 to 1 1/3 in) and occasional vertical joints spaced several centimeters (2 to 6 in) apart. The diamicton matrix is unoxidized (dark gray), while the joints are oxidized and have some secondary iron oxide coatings

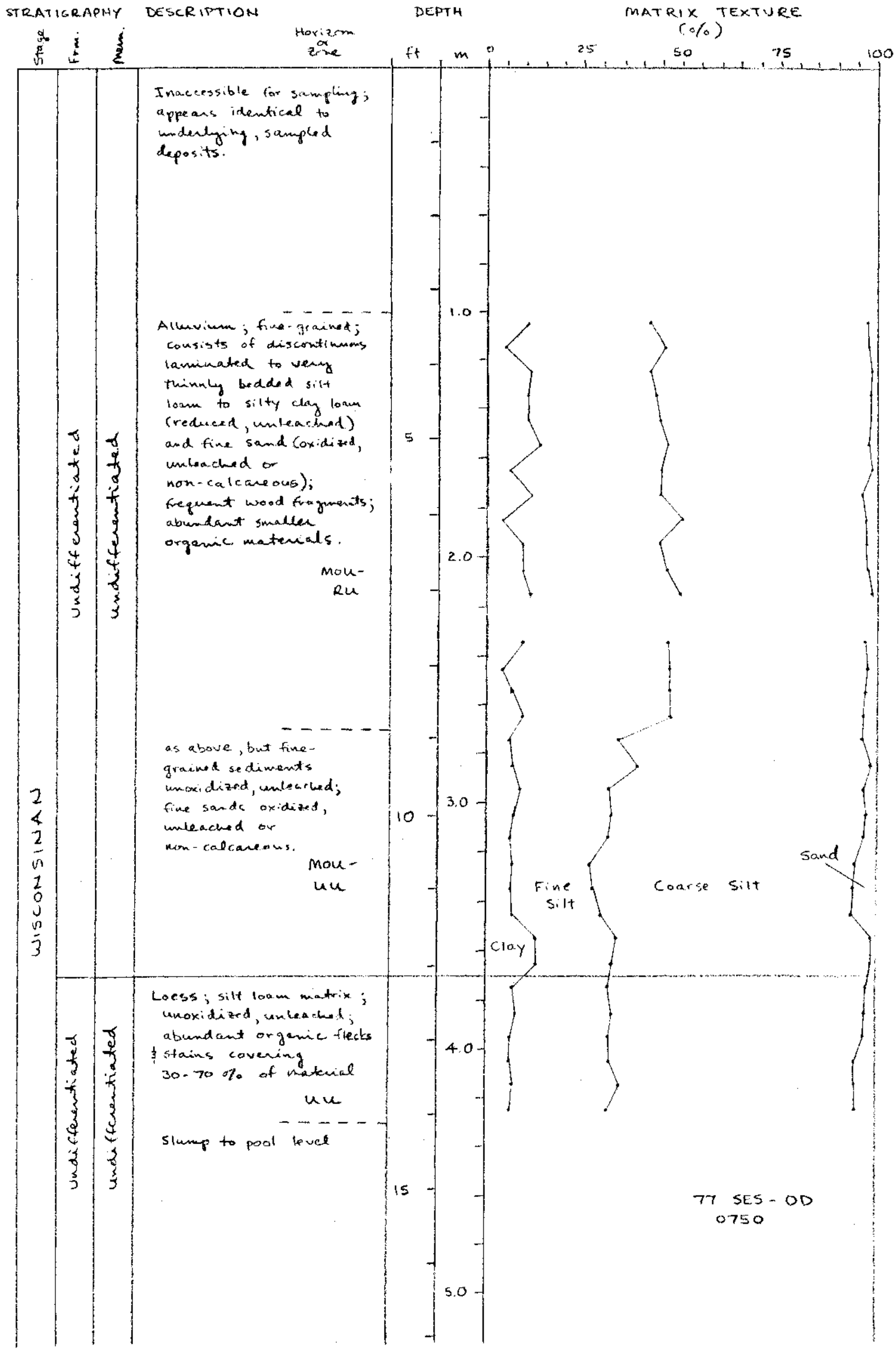
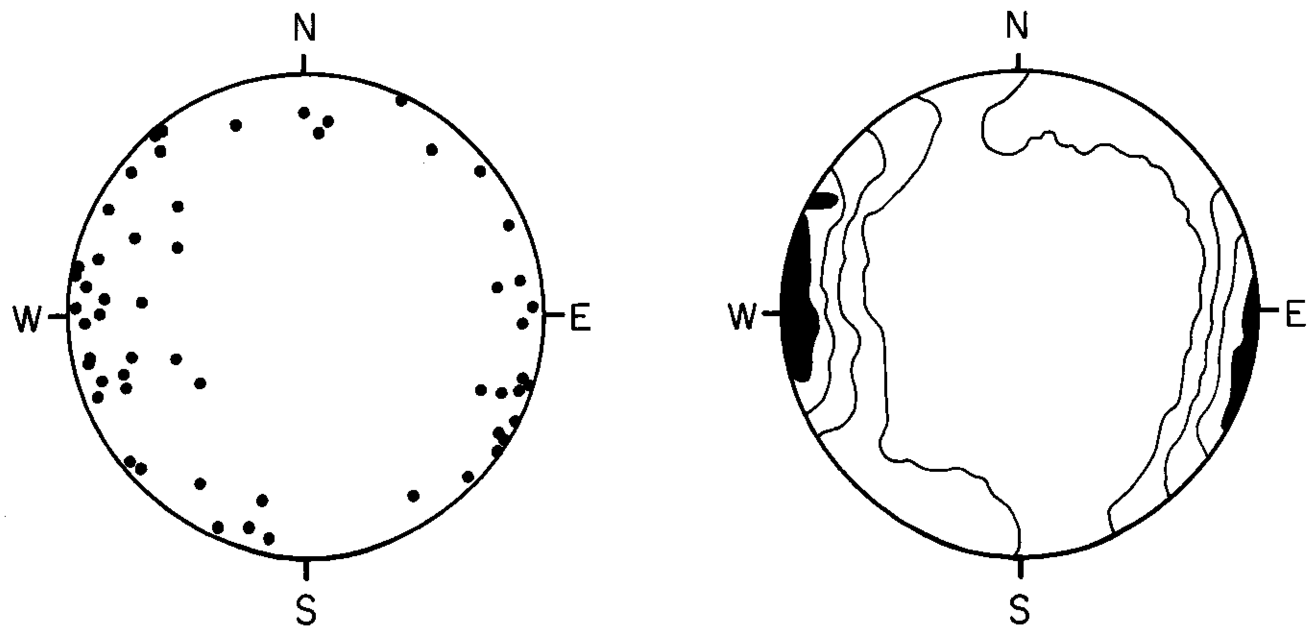


Figure 2-9. Stratigraphy and particle-size of profile D, Section O.

SAYLORVILLE EMERGENCY SPILLWAY

Section O

FABRIC DIAGRAMS OF TREND AND PLUNGE
OF 58 LOG AND WOOD FRAGMENTS



	Az.	Dip	Sig.
S_1	275°	6°	0.64
S_2	185°	0°	0.30
S_3	95°	84°	0.06

Figure 2-10. Fabric data for wood fragments in late Wisconsinan-age Des Moines Lobe diamicton at Section O. Data plotted on lower hemisphere, Schmidt equal-area projection are shown on the left. Contoured equal-area projection (contoured according to the method of Kamb, 1959) shown on right; contour interval = 2σ. Data from eigenvector analysis (Mark, 1973) shown at bottom.

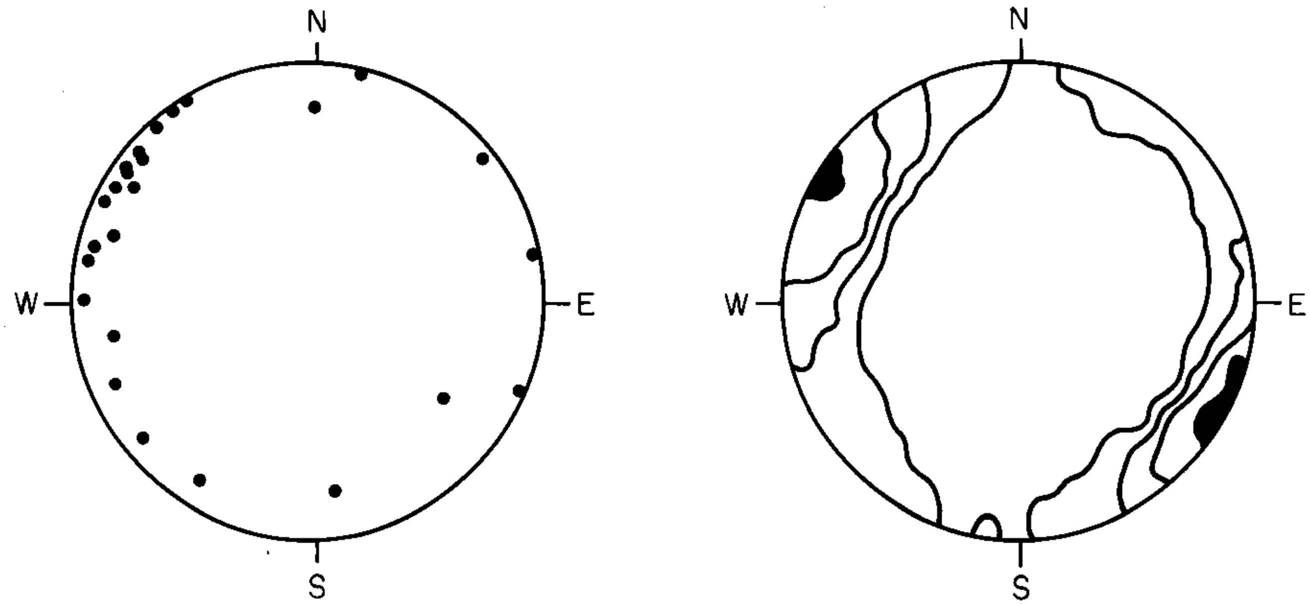
SAYLORVILLE EMERGENCY SPILLWAY

SECTION O

PEBBLE FABRIC AT SITE OE

Contour Interval = 2σ

$n = 25$



	Az.	Dip	Sig.
S_1	296°	4°	0.68
S_2	205°	5°	0.29
S_3	66°	83°	0.03

Figure 2-11. Pebble fabric data from Des Moines Lobe diamicton at site OE shown on Figure 2-6. Data plotted on lower hemisphere, Schmidt equal-area projection are shown on left. Contoured equal-area projection (contoured according to the method of Kamb, 1959) shown on right. Data from eigenvector analysis (Mark, 1973) shown at bottom.

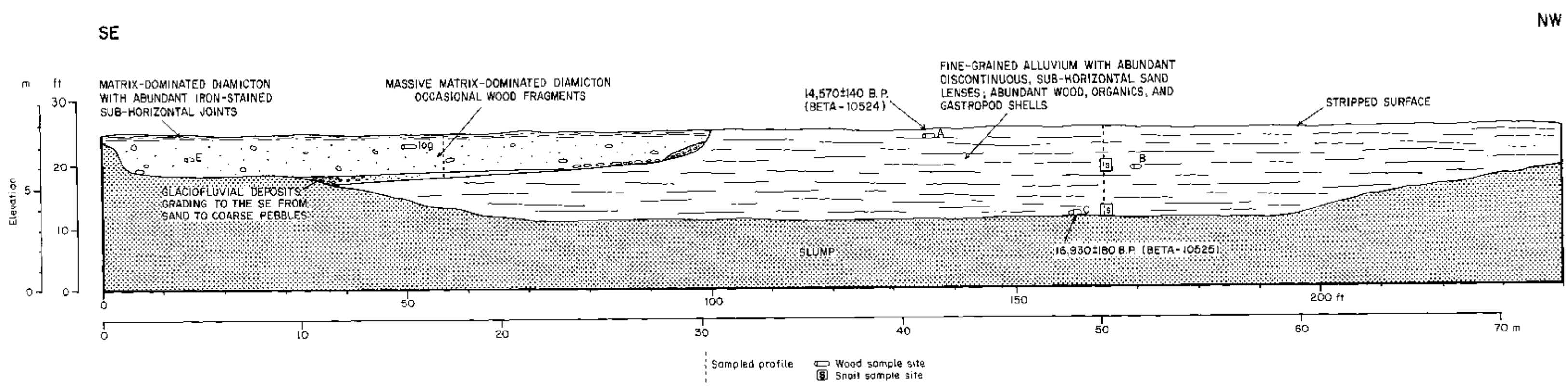


Figure 2-12. Cross-sectional sketch of the stratigraphy exposed at Section 1.

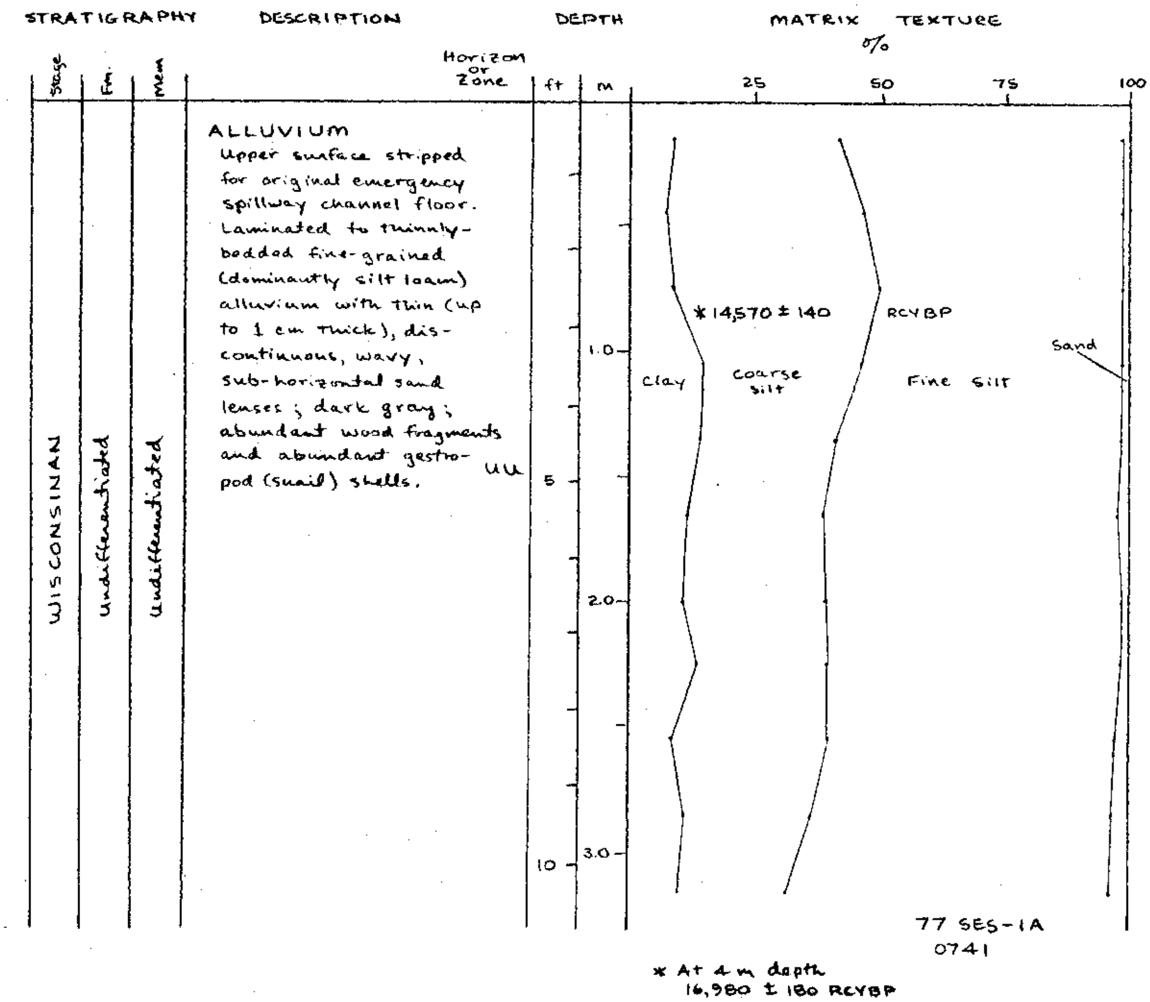


Figure 2-13. Stratigraphy and particle-size of profile A, Section 1. Profile location shown on Fig. 2-12.

along them. It is uncertain what has caused this sub-horizontal jointing. Three possibilities include: shearing related to lodgement depositional processes (Dreimanis, 1976, among many others); vertical stress relief resulting from removal of overlying material, perhaps enhanced by residual, glacially-induced stresses within the till; or disturbances caused by stripping and grading of the original emergency spillway channel floor.

As at Section 1B, the Des Moines Lobe diamicton at Section 0 also has a sub-horizontal, planar, erosional lower contact on Des Moines Lobe glaciofluvial deposits. However, the character of the diamicton is wholly different from that at Section 1B. An indistinct, sub-horizontal horizon of individual cobbles occurs 0.15 to 0.5 m (0.5 to 1.5 ft.) above the base of the diamicton across much of the exposure. The diamicton includes extremely abundant wood fragments of all sizes up to log size. This section, in fact, probably contains as much or more wood and log fragments than any other till exposure in the Midwest. The diamicton also includes abundant inclusions of fine-grained

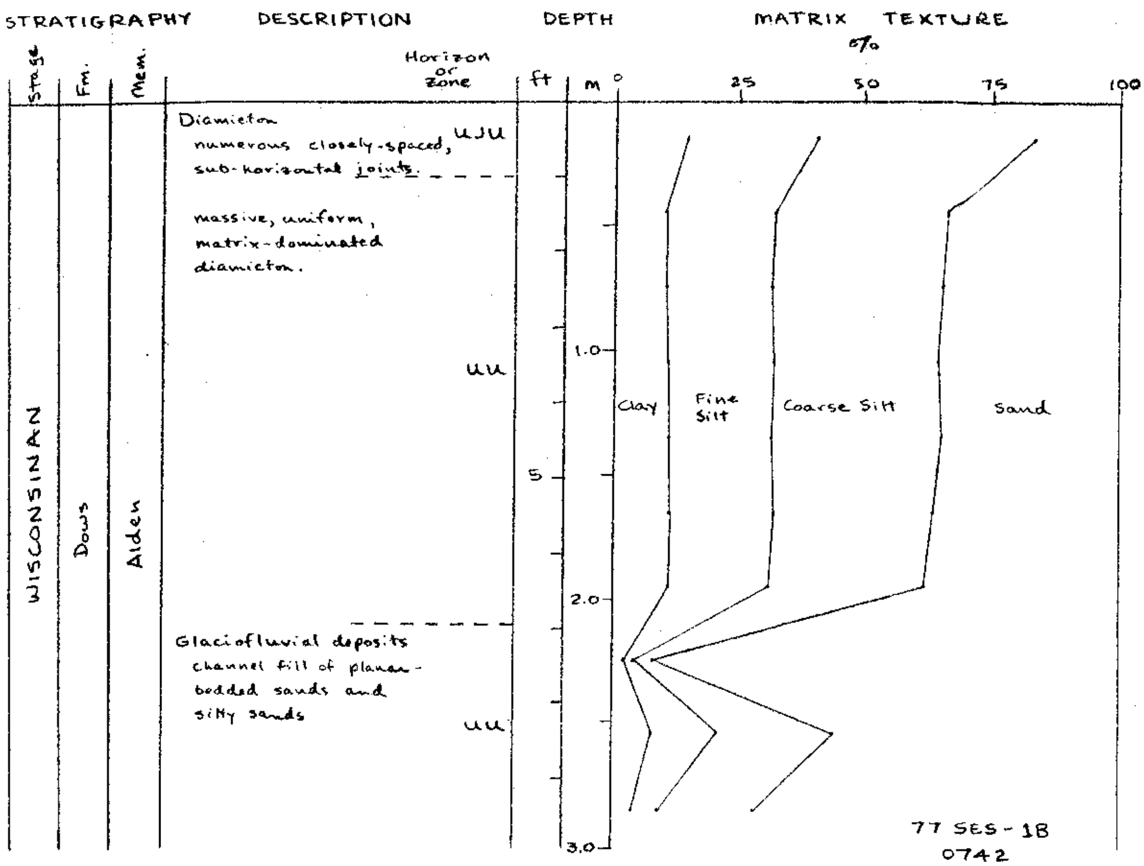


Figure 2-14. Stratigraphy and particle-size of profile B, Section O. Profile location shown on Fig. 2-12.

sediment, much of which appears to be loess. When this exposure was originally studied in the Fall of 1984, all of the deposits were unoxidized, dark gray. Tracing (seeing) the contacts between the fine-grained, loess-like deposits and the fine-grained diamicton was extremely difficult. By the Fall of 1985, differential oxidation of the deposit types on the outcrop face has made identification and delineation of the units possible. Many of the fine-grained deposits occur as large, lenticular, imbricated block inclusions 1 to 2.5 m (3 to 8 ft) long, 0.15 to 0.3 m (0.3 to 1 ft) thick, dipping to the W-NW (roughly parallel to the paleovalley crossing the emergency spillway channel) at 25 to 35 degrees.

Small-scale channel fills, up to 0.2 m (8 in) wide and 0.15 m (6 in) deep, occur interbedded in the diamicton at a few locations along the exposure; 2 occur along the left (NW) side of the outcrop. These channel fills appear virtually undeformed, but they have been rotated somewhat from their original depositional orientation.

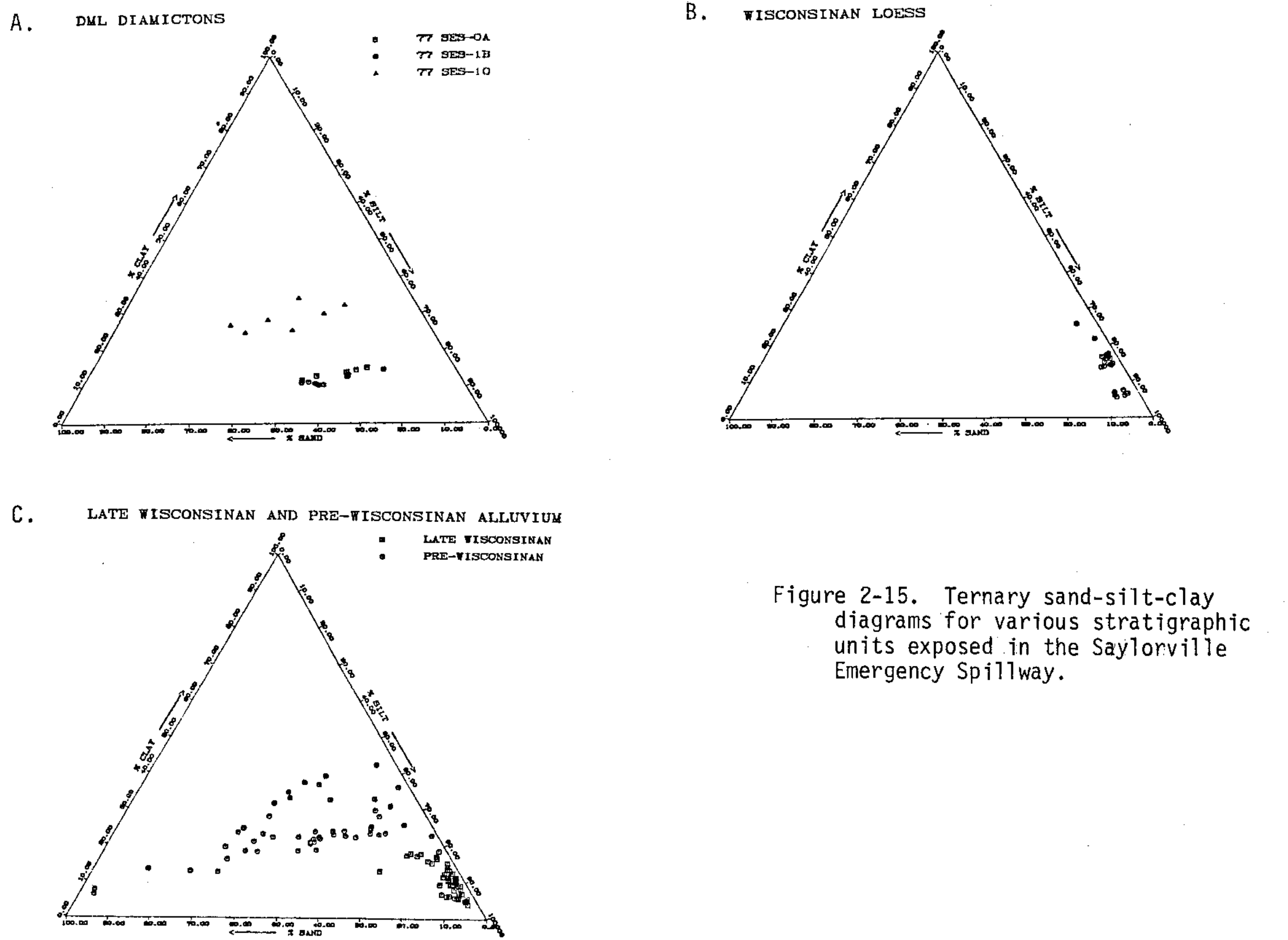


Figure 2-15. Ternary sand-silt-clay diagrams for various stratigraphic units exposed in the Saylorville Emergency Spillway.

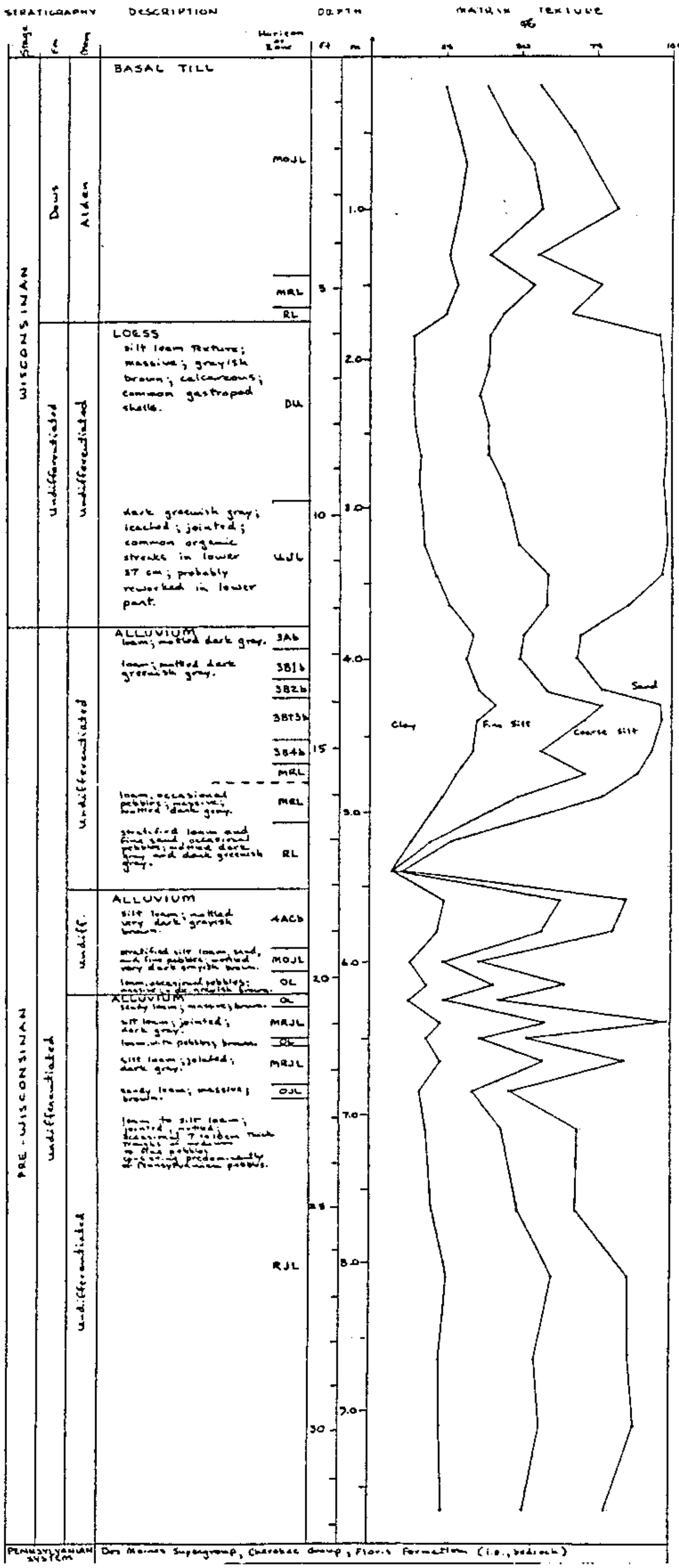


Figure 2-16. Stratigraphy and particle-size of described Section 10.

The upper half meter of diamicton across the outcrop, like that at Section 1B, is extensively jointed with numerous, closely-spaced, sub-horizontal joints. The rest of the diamicton body includes conjugate sets of dipping joints, most of which appear to have slickensides developed along them. On the original outcrop, the diamicton and associated inclusions were all unweathered, unoxidized (dark gray), unleached. During the past year and a half the deposits have begun to oxidize.

During initial study of the section in the Fall of 1984, two particle-size profiles were sampled to generally characterize the stratigraphy of the site. Profile 0A (Fig. 2-7) was sampled where the section consisted of massive diamicton, while Profile 0B (Fig. 2-8) was sampled where the section consisted of interbedded diamicton and lenses of sediment. In both profiles, the diamicton had silt loam matrix textures similar to those in Section 1B.

The diamicton at Section 10 was poorly exposed, but it was entirely different than those at Sections 0 and 1B. It appeared to be a massive, matrix-dominated diamicton. The matrix texture of the diamicton was very variable, however, and ranged from clay loam to loam (Figs. 2-15B and 2-16). These textures are anomalous for Des Moines Lobe diamictons, and include some of the highest clay percentages yet encountered. The Des Moines Lobe diamicton at this site is also anomalously weathered, the high degree of secondary alteration being similar to that found in weathered Pre-Illinoian age tills. At the described section, the diamicton is leached throughout. The upper part of the unit is jointed, and oxidized; abundant secondary mottles are present. The described section must have been near the original land surface, accounting in part for the observed weathering. The relatively high degree of secondary alteration at this site may also be related to the high content of locally-derived Pennsylvanian clasts. Decomposition of pyrite from these clasts may account for the oxidation, leaching, and abundant mottling. This section is located nearest the highest portions of the Pennsylvanian subcrop, and the high proportion of Pennsylvanian clasts is probably related to the local incorporation of these lithologies. The high clay content of the diamicton at this section may also be related to local incorporation of Pennsylvanian mudstones, and perhaps to weathering-related decomposition of these mudstone clasts in the diamicton. Observations to confirm these contentions could not be made because of the poorly-exposed nature of the upper part of this section, but these explanations do at least provide a believable cop out.

Primary and Secondary Properties: Glaciofluvial deposits. Des Moines Lobe glaciofluvial deposits occur in Sections 0 and 1. They are thin, less than 1 m (3 ft) thick, incised into late Wisconsinan-age alluvial deposits, and are truncated by planar erosion surfaces of the overlying Des Moines Lobe diamicton deposits. At Section 0 the glaciofluvial deposits consist of thin, lenticular beds of planar-stratified and low-angle cross-stratified sands and silty sands. The top of this bedding has been truncated by the planar, sub-horizontal base of the Des Moines Lobe diamicton.

At Section 1B the glaciofluvial deposits consist of small-scale channel fills. These fills are characterized by simple vertical accretion with planar bedding mimicking the channel geometry. Like the glaciofluvial deposits at Section 0, these deposits are undeformed, but erosionally truncated by the planar base of the overlying Des Moines Lobe diamicton. At both sections, the Des Moines Lobe glaciofluvial deposits are unoxidized and unleached (i.e., unweathered).

Depositional Environment: Diamicton deposits. In recent years geologists have become aware of the great complexity of sedimentation in glacial environments (note the complexity shown in Boulton, 1971, 1972; Sugden and John, 1976; Lawson, 1979a; Eyles and Miall, 1984; for example). This complexity, unfortunately, can lead to problems in interpretation. There can be considerable overlap in facies between different glacial depositional environments, and in those cases where facies or structures indicative of deposition in a single depositional environment are absent, a unique, unequivocal interpretation may not be possible (Kemmis et al., 1985). Such a situation exists for the Des Moines Lobe diamicton deposits exposed in the emergency spillway. Primary depositional features present allow us to confidently interpret the diamictons as 'basal till,' deposits formed subglacially, although more refined interpretations of precise depositional processes, such as lodgement (by actively moving ice at the pressure melting point) or melt out (by passive melt-out from stagnant ice) remain problematic.

Four primary features of the Des Moines Lobe diamicton deposits suggest deposition in a subglacial environment: (1) planar erosion surfaces at the base of the deposits; 2) imbricated inclusions of local substrate materials (such as loess) and associated joint (fault) structures in the diamicton ; 3) consistently oriented wood fragments and pebble fabrics in the diamictons; and 4) uniform matrix textures in the massive diamictons. Planar erosion surfaces are indicative of erosion by an actively moving, rigid ice mass. The imbricated block inclusions of local substrate are typical of compressional flow regime which can occur either in basal ice near a glacier terminus or against the stoss (upstream) side of an obstacle on the glacier bed.

Consistently-oriented wood fragments (Fig. 2-10) and pebble fabrics (Fig. 2-11) were found in the Des Moines Lobe diamicton at Section 0. The 'fabric' or orientation of particles in a deposit may be a useful indicator of depositional process or environment. The pervasive stress field in glaciers imparts a preferred orientation to particles in the deposit (till) depending on flow conditions (compressive and extending) and particle shape (Holmes, 1941; Boulton, 1971; Drake, 1974; Lawson, 1979b; among many other studies). Resedimentation processes in the glacial environment such as sediment gravity (debris) flows, spall collapse, etc., lack the strength or pervasive stress field to promote a consistent, well-oriented fabric in the deposits (Lawson, 1979b; Boulton, 1971; among others).

The fabrics of wood fragments and prolate-shaped (elongate) pebbles in the diamicton at Section 0 are in the range of those characteristic of subglacially-deposited diamictons (basal tills). Fabric measurements on wood fragments were made because wood was so abundant in Section 0 (58 fragments were measured across the outcrop) and because twigs and logs are of ideal elongate, 'prolate' shape. The fabric for the wood fragments is roughly bimodal with a dominant W-NW/E-SE mode and a weak N-S mode. The dominant mode is parallel to the axis of the paleovalley crossing the emergency spillway channel and is in the same direction as the imbricated block inclusions of loess. It is uncertain why there is a bimodal fabric for the wood fragments. Perhaps some of the fragments were rolled along transverse to the direction of greatest stress while others were 'streamlined' parallel to the greatest stress direction.

Just one pebble fabric was taken in the diamicton. This fabric was measured over a small area near the center of the outcrop (Fig. 2-6), 0.5 m (1.5 ft) above the base of the Des Moines Lobe diamicton and approximately 0.5 m (1.5 ft) below one of the imbricated block inclusions of loess. Twenty-five elongate, prolate pebbles were measured. The pebble fabric is very similar to that of the wood fragments, suggesting that both had been oriented by the same pervasive stress field. A possible clue to some of the scatter in the pebble fabric was observed as the fabric was measured. There appeared to be micro-zones in the diamicton, possibly joint-bounded, where elongate particles all had similar orientation, while other joint-bounded micro-zones had slightly different orientations. In layered metamorphic rocks, cleavage refraction occurs across different layers because the differing ductility of the layers causes some layers to undergo more strain than others. At Section 0, imbricated block inclusions impart a 'layering' to the deposit. This layering, however, is highly irregular as the blocks are neither continuous nor parallel-sided. In response to subglacial glaciotectonic stresses, differential strain, perhaps across joint-bounded areas in the deposit, resulted in differential re-orientation of prolate-shaped clasts accounting for the observed scatter in the pebble fabric. This interpretation should be regarded as preliminary, as much more work on the structural features of this section need to be done. Fortunately, the differential oxidation between different deposit types at this section now allows one to confidently and precisely map contacts and structures. Further study is planned.

Finally, the massive, textural homogeneity of the Des Moines Lobe diamictons at Sections 1B and 0 are also typical of basal tills on the Des Moines Lobe (Kemmis et al., 1981). Various resedimentation processes (e.g., Lawson, 1979a, 1982) cause some resorting and the development of a host of sedimentary structures (basal tractional gravels, winnowed horizons, water-escape structures, graded bedding, load structures, etc., are all possible) none of which are present in the massive, texturally-uniform diamictons.

Diamictons deposited subglacially (basal tills) may be deposited either by 'lodgement' from actively moving ice at the pressure melting point or passively by melt-out from stagnant ice. As yet, the authors have not observed any structures clearly definitive of deposition solely by one or the other of these processes. A melt-out origin might be favored because there is a planar, undeformed lower contact even though large-scale, high-angle deformation structures (the imbricated block inclusions) occur less than a meter (3 ft) above the contact. Such deformation could occur in debris-rich basal ice unrelated to glacial erosion at the spillway exposure; subsequent melt-out from the debris-rich basal ice would later preserve the imbricated structures. In any case, at this time there are few structures present in the emergency spillway exposures which indicate specific depositional processes for the basal tills.

Depositional Environment: Glaciofluvial deposits. Des Moines Lobe glaciofluvial deposits are preserved at Sections 1B and 0. At Section 1B the glaciofluvial deposits are dominantly small-scale channel fills less than one meter (3 ft) deep and from 1 to a few meters (3 to 15 ft) wide incised into the underlying late Wisconsinan-age alluvium. The channel fills are dominantly simple vertical-accretion fills in which the stratification mimicks the channel geometry. The fills are dominated by planar-bedded sands and silty sands, suggesting deposition in relatively low energy glaciofluvial channels.

At Section 0 the edges of the glaciofluvial deposits are not exposed, and thus it is not possible to know the geometry and scale of the channel system there. The total sequence preserved is 1 meter (3 ft) or less in thickness, and consists of thinnly-bedded, irregularly bounded sets of planar-bedded and low-angle cross-bedded sands and silty sands. These strata suggest deposition by vertical accretion on the channel floor and migration of small-scale sand waves. This sequence, too, does not appear to have been a very high energy glaciofluvial environment. It is uncertain if the glaciofluvial deposits at either Sections 0 or 1B were proglacial or subglacial deposits.

Wisconsinan Alluvium

General. Fine-grained late Wisconsinan-age alluvium is extensively exposed in the central and downstream portions of the emergency spillway (Section 0, Fig. 2-6; and Section 1, Fig. 2-12). At Section 1 the alluvium is buried by Des Moines Lobe basal till (Dows Formation, Alden Member). Prior to grading of the emergency spillway Des Moines Lobe till probably covered the alluvium over the entire area. At Section OD the late Wisconsinan-age alluvium buries Wisconsinan-age loess (Fig. 2-9). The base of the alluvium is buried by slump at the other sections. Four radiocarbon dates from wood buried within the alluvium at Section 0 and Section 1 indicate that the alluvium accumulated between about 17,000 and 14,000 years ago (Figs. 2-6 and 2-12).

Primary Properties. This unit consists of laminated to thinly-bedded fine-grained (dominantly silt loam) alluvium with thin (up to 1 cm thick) discontinuous (lenticular), wavy lenses of fine to medium sand. On fresh exposure the unit is unoxidized and unleached (UU). The fine-grained parts of the deposit are dark gray (N 4/0) while the sand lenses are gray (N5/0). We interpret these colors and the oxidation state indicated by them to be primary features of the deposit. The unit also contains wood and other plant macrofossils (Baker, this volume), mollusc shells (Frest, this volume), and fossil insects.

Secondary Properties. Few secondary alteration features are evident in the late Wisconsinan-age alluvium. As a result of the recent exposure of this unit to the atmosphere, portions of it are oxidizing. Oxidation is most pronounced in and around the sand lenses. Fine-grained portions of the deposit also oxidize to an olive brown color. These color changes are surficial and the original, unoxidized colors of the deposit can be observed by scraping and digging into the exposure.

Depositional Environment. Sedimentary structures (bedding features) indicate that this deposit is alluvium. The absence of coarse grains and channel forms indicate that this is not an active channel deposit. The nearly planar bedding, fine texture, and thin, discontinuous lenses of fine to medium sand suggest a relatively low energy fluvial environment. The features observed in this unit in the emergency spillway exposures are consistent with a rapidly aggrading floodplain environment. The thin sand lenses are interpreted as small-scale splay deposits originating during flood events. Fauna associated with this unit are also consistent with a floodplain environment (Frest, this volume).

The geometry of this unit is very poorly understood. The northern valley wall is present north of the Holocene drainageway which crossed the emergency spillway prior to construction. The southern part of the deposit is unknown, but occurs farther south than the southernmost emergency spillway exposure (Section 0). We suggest that the late Wisconsinan-age alluvium was deposited in a backswamp area associated with a high-order stream valley.

This is the only locality in the state where such fine-grained late-Wisconsinan floodplain alluvium has been observed and described. Fossil plants, molluscs, and insects associated with this deposit provide us with a unique picture of a relatively large, high-order stream environment just prior to the Des Moines Lobe glacier advance in central Iowa (see papers by Baker and by Frest, this volume).

Wisconsinan Loess

General. Wisconsinan-age loess is exposed at Sections 2 and 10 in the emergency spillway (Fig. 2-1). This deposit is buried by either Holocene alluvium (Section 2) or by Des Moines Lobe Dows Formation (Alden Member) glacial tills (Section 10). The loess, in turn, buries pre-Wisconsinan age alluvium in these exposures.

Loess beneath Des Moines Lobe glacial deposits is a common occurrence in the southern portion of the Des Moines Lobe landform region (Ruhe, 1969; Kemmis et al., 1981). Numerous radiocarbon dates indicate that ice of the Des Moines Lobe glacier buried the loess around 14,000 years ago. In Illinois, Wisconsinan loess found in a similar stratigraphic position (buried by Wisconsinan-age Wedron Formation) is rock-stratigraphically classified as a formation, the Morton Loess.

The loess began accumulating in south-central Iowa around 21,000 years ago. Loess buried beneath the Des Moines Lobe till is equivalent to portions of the loess that form the surficial deposit outside the margins of the Des Moines Lobe.

Primary Properties. Loess exposed in the emergency spillway has properties typical of that found beneath Des Moines Lobe glacial deposits elsewhere. The deposit is silt loam in texture with low sand content (less than 5 percent here) (Fig. 2-15B). The loess is massive, unbedded. The matrix is calcareous and mollusc shells are common.

Secondary Properties. Post-depositional alteration of the loess has produced many of the morphologic features observable in the deposit today. Most of these alterations are weathering-related, but are not called pedogenic here since they have not resulted in the development of soil horizons and secondary soil structure. Some of the most obvious features of the loess here are its grayish brown color with brown mottles and secondary, vertically elongate iron concretions (pipestems) (see descriptions for Sections 2 and 10, Appendix 2-1). The grayish brown colors, mottles, and pipestems are genetically related. When loess is this color and has mottles and/or secondary accumulations of iron oxides (pipestems or tubules) associated with it, it is referred to as deoxidized (Hallberg et al., 1978). Loess exibiting these colors has been found to have low total free iron content relative to loess exibiting yellower and browner "oxidized" colors (Daniels et al., 1961; Bradbury et al., 1977; Hallberg et al., 1978). Originally the loess, since it is a windblown deposit, was probably in an oxidized state. Shortly after its deposition, or following burial by Des Moines Lobe glacial deposits, the loess became saturated. Iron compounds were mobilized and migrated toward macropores or other areas where a change in Eh (oxidation potential) caused precipitation as mottles or concretions. In the lower portion of Section 10 the loess exibits a dark greenish gray color (5GY 4/1). When loess is this color it is referred to as unoxidized (Hallberg et al., 1978). Iron ions in this zone tend to be dominated by the ferrous (Fe^{2+}) form. Also associated with the unoxidized zone of the loess in Section 10 are smudges of organic material. The presence of these organics may promote the unoxidized state of the loess here as microbial decomposition of the organic matter consumes any oxygen reaching this zone. This would retard segregation of the soluble iron compounds under the saturated conditions existing in the deposits.

Small, soft, secondary accumulations of opaque ferro-manganese compounds, referred to as oxides in the descriptions (Appendix 2-1), probably originated under conditions analogous to those of the iron-oxide concretions. Manganese oxides show a greater tendency to occur in concretions than iron oxides, probably because manganese is reduced to the relatively soluble Mn^{2+} ion more readily than the ferric ion is reduced to the ferrous ion (Allen and Fanning, 1983) and thus is more mobile. Manganese oxide accumulations in soils are very dark brown to black and can be easily confused with accumulations of organic matter. These two can be easily distinguished since only the manganese oxides effervesce in hydrogen peroxide.

Soft secondary accumulations of carbonate minerals (calcite) are abundant in the loess at Section 2. Carbonate concretions are ubiquitous in unleached loess sections in Iowa. The mobilization (dissolution and movement with the soil solution) of carbonate ions in the loess is primarily produced by weathering associated with soil development at the land surface. The secondary carbonate concretions form when carbonate in solution segregates and precipitates lower in the weathering zone profile as the soil water solution becomes saturated with respect to calcium carbonate. Accumulation of secondary carbonates is indicated in standard weathering zone terminology in the descriptions by the arabic numeral 2 at the end of the weathering zone designation; for example MRU2 (Hallberg et al., 1978).

Section 10 also exibits secondary properties associated with soil development in the lower 84 cm of the loess (Appendix 2-1). The organic smudges in this part of the deposit accumulated when this deposit formed at the land surface during the Wisconsinan. These are equivalent to O or A (topsoil) horizons which develop at or near the present land surface as result of the accumulation of litter, shallow roots and other organic matter. Another indication that this zone has been altered by pedogenic activity is the fact that it is noneffervescent (leached). Loess is originally calcareous when deposited. This zone was probably leached of primary carbonates when it was near the land surface.

This lower zone at Section 10 is correlative with the 'basal loess sediment,' an informal unit recognized in the lower portion of the Wisconsinan loess throughout Iowa. This zone accumulated during the onset of loess deposition in Iowa when the rate of loess deposition was slow enough that the deposit was often leached before being buried. In many areas a paleosol, the 'basal loess paleosol,' is developed into the basal loess sediment. The Farmdale Soil is in this identical stratigraphic position in Illinois (Follmer, 1983).

Another phenomena often associated with the basal loess sediment is a mixing zone at the base of the deposit where subjacent material is mixed with lower portions of the basal loess sediment. Such a mixing zone is evident in the particle-size plot of Section 10. The lower approximately 25 cm of the "loess" contains much more sand than the overlying loess because of mixing with underlying pre-Wisconsinan deposits. This mixing probably resulted from biogenic activity and slopewash when this part of the section constituted the land surface at the beginning of loess deposition.

Depositional Environment. Late Wisconsinan-age loess was deposited in south-central Iowa on an eroded landscape with surface relief similar to that present south of the Des Moines Lobe today. Soils of variable morphology were developed on that landscape. At the time loess deposition began the landscape was occupied by a spruce-larch forest (Baker et al., 1980). Based on pollen studies in eastern Iowa the forest was probably closed at the onset of loess deposition, then began to open as loess deposition rates increased (Baker et al., 1980; R. G. Baker, personal communication). As the loess fell, it accumulated in several environments on the land surface. Three of these are represented in the emergency spillway. Loess at Section 2 fell on a well or moderately well-drained portion of the landscape, while that at Section 10 fell on an adjacent, poorly-drained area. Both Sections 10 and 2 are located on the northern margin of a pre-Des Moines Lobe valley. Aspects of the paleo-topography will be discussed in a following section. The third environment in which loess fell in this area is on an actively aggrading Wisconsinan-age floodplain discussed previously.

Pre-Wisconsinan Age Alluvial Fills

General Aspects. Another unique feature of the Quaternary exposures in the emergency spillway is the presence of relatively fine-grained pre-Wisconsinan age alluvium. The alluvium fills a valley cut into the Pennsylvanian rocks south of the access road crossing the emergency spillway (Figure 2-1). Described exposures of this unit are given for Sections 2 and 10 (Appendix 2-1). Wisconsinan-age loess, Des Moines Lobe till and glaciofluvial deposits, and Holocene alluvium/colluvium bury the pre-Wisconsinan alluvium. Various unconformities (erosion surfaces and/or soils) separate the pre-Wisconsinan and Holocene deposits.

Primary Properties. This unit is the most variable of the Quaternary deposits exposed in the emergency spillway, ranging from fine-grained clay loam to pebbles. Numerous primary sedimentary features are preserved in these sediments. Several fining-upward sequences are present. These usually consist of sand or pebbly loam grading upward to clay loam or silt loam. Often 10-20 cm thick troughs of clast- or matrix-supported pebbles and cobbles occur at the base of a fining-upward sequence. They truncate underlying deposits. The troughs are greater than 10 m (30 ft) in lateral extent. Pebbles and coarser clasts are dominated by local Pennsylvanian lithologies, although erratic clasts are also present.

Secondary Properties. Post-depositional alterations have extensively modified the pre-Wisconsinan alluvium. Paleosols are developed into the upper portion of the pre-Wisconsinan deposits at both Sections 2 and 10 (Appendix 2-1). The buried soils are morphologically well expressed. The uppermost paleosol at Section 10 developed on a poorly-drained landscape position. This is indicated by the gray and dark greenish gray matrix colors (5Y 4/1 and 5GY 4/1-5G 4/1) and greenish gray mottles. Slickensides are common in the clay loam textured Bg1b and Bg2b (subsoil) horizons of this paleosol. The slickensides develop as a result of shrink-swell phenomena induced by wetting and drying and/or freezing and thawing. The Cg horizon material beneath this soil also has a dark, reduced color indicative of poor drainage.

In contrast to the soil developed at Section 10, the buried soil developed in the upper portion of the pre-Wisconsinan alluvium at Section 2 is moderately well-drained. The lighter-colored brown matrix colors, in conjunction with yellowish brown mottles in the B horizon, indicate that it developed on a moderately well-drained landscape position. This soil also has a Btb horizon (zone where significant secondary accumulation of clay has occurred). Note the cutans (clay coatings) on ped faces in this horizon (200-235 cm in the description, Appendix 2-1). The 3Eb and 3EBb horizons above the 3Btb are the zones from which the clay eluviated (moved). The 3EBb horizon also exibits thin discontinuous silans, zones where the iron and/or clay has been stripped from the sand and silt grains or where clay- and silt-size quartz has accumulated on the ped faces (Brewer, 1964). From a distance these zones appear as grayish brown patches.

The marked clay bulges in these soils are probably depositional in origin. The profile at Section 2 does show evidence of clay translocation in the form of cutans, but the overlying 3EBb is also clay loam texture. Heavy-textured soils developed into the upper portion of fining-upward sequences are common occurrences on floodplains. Soils developed in heavy-textured deposits also tend to exibit finer size and stronger grade soil structure than do soils formed under similar conditions in lighter-textured deposits. This phenomena can lead to erroneous interpretations of the relative degree of soil profile development (which is often equated with length of weathering) when comparing soils developed in alluvium of differing textures.

Another buried soil is developed lower in the pre-Wisconsinan alluvial sequence at Section 10 between a depth of 551 and 590 cm. This soil has an AC soil profile and would be classified as an Entisol (soil classification is discussed in a publication by the Soil Survey Staff, 1975). Soils such as this can develop in a very short time in floodplain environments.

Mottles are a common feature in the pre-Wisconsinan alluvium. These developed during periods of alternate saturation and aeration as outlined in the discussion of mottles in the loess.

Subvertical joints are evident in the lower 4m (13 ft) of Section 10. These may have been produced during dry periods prior to the late-Wisconsinan. Iron oxides have accumulated along the joint faces.

The original carbonate status of the pre-Wisconsinan alluvium is unknown. Today the deposit is noncalcareous throughout.

Depositional Environment. Bedding structures, texture of the deposits, presence of fining-upward sequences, and superimposed paleosols all indicate that this is an alluvial deposit. The size of channels observed suggest that this alluvium was deposited in a large valley. The fine texture and general absence of bedding structures in the bulk of the deposit suggest that these are overbank deposits.

The valley was incised into Pennsylvanian bedrock, and its northern valley wall was located at approximately the location of the access road crossing the emergency spillway today. Similar pre-Wisconsinan alluvial deposits are exposed north of the Visitor Center along the eastern shoreline of Saylorville Lake (Bettis and Hoyer, in preparation). The northern valley wall is exposed along the eastern shoreline. In that area Pre-Illinoian age glacial till forms the valley wall. A 'Late Sangamon' Paleosol is developed on the till surface. That paleosol descends into the pre-Wisconsinan alluvium and bifurcates into several, superimposed paleosols developed into the alluvium.

The Latest Holocene:
features of the 1984 emergency spillway channel ('Saylorville Canyon')

Besides the spectacular geology exhumed along the floor and walls of the emergency spillway, the channel itself displays a variety of interesting erosional and depositional features. The Pennsylvanian strata have locally influenced channel erosion in a number of ways. The stepped longitudinal profile in the Pennsylvanian-age rocks results from the differing erodability of the various Pennsylvanian strata. Related to this lithologic control is the undercutting of more competent rocks (such as the Swede Hollow Fm. sandstone) as softer underlying rocks (such as the Swede Hollow Fm. shales) were eroded away.

In map view, the erosion of the Pennsylvanian rocks takes on a V-shape, widening down channel. Presumably this shape results from greater velocities, and hence greater erosion, in the center of the emergency spillway channel.

In the uppermost reaches of the emergency spillway channel, above where the Swede Hollow Fm. sandstone is breached, both a main and side channel system were cut in the overlying fill materials. Downstream of the area of bedrock control in the channel, two pools, part of a pool-and-bar sequence, were scoured in the Quarternary deposits (Fig. 2-1). Also downstream, the valley widens in two loops along the left bank at described Sections 0 and 2 (Fig. 2-1). In both cases, the widening resulted where flows in the spillway were able to easily excavate cohesionless materials in the emergency spillway walls: at Section 0 stratified glaciofluvial sands between the Des Moines Lobe till and fine-grained late Wisconsinan-age alluvium (Figure 2-6) were excavated; at Section 2 cohesionless man-made fill of Pennsylvanian rock fragments (which infilled the former side valley crossing the site) were eroded (Figure 2-2, cross-section C-D).

Depositional features in the emergency spillway channel include joint-bounded blocks of sandstones left as lagged-out remnants in the upper reaches. Downstream, where the channel is cut in Quaternary deposits, 2 bars, megaforms, were deposited as part of a pool-and-bar sequence. The bars are conspicuously composed of imbricated 'gravel clusters' (Brayshaw, 1984, 1985), macroforms consisting of large blocks of Pennsylvanian bedrock oriented with their long axes transverse to flow (i.e., rollers, oriented across the valley) upon which other bedrock blocks are progressively imbricated.

It should be noted that neither the erosional nor depositional features were deposited by a stream in equilibrium. Flooding in the emergency spillway was a very short-term, high-magnitude event where features rapidly evolved, but full channel equilibrium, which would have resulted from continued flow, was never achieved. Because of this disequilibrium condition, relating various erosional and depositional features to observed flow conditions (stream power, etc.) would be incorrect.

In the little more than a year since the emergency spillway was cut, a number of changes have taken place. Large rotational landslides have occurred along select portions of the spillway channel, particularly along the right (southwest) bank. In 1985, vegetation (weeds) has become firmly established along most areas of the spillway channel. Many large blocks of Pennsylvanian bedrock in the channel bars have rapidly decayed simply because of subaerial exposure. In particular, boulders of mudstone and shale, actively transported by the spillway flows are now partially or totally disaggregated; the mudstone boulders now largely consist of disaggregated piles of gray, red, or bluish mud, depending on which stratigraphic unit they are from; and the more fissle shales are disaggregating by splitting along cleavage planes.

Suggestions for Further Study

It should be obvious from the preceeding discussions that there is still alot to be learned from the Quaternary deposits exposed in the emergency spillway. The following is by no means a complete list of research topics which could be pursued.

1) Sedimentology of the Des Moines Lobe deposits. Numerous bedding features and deformation structures are present in these deposits. Analysis of these structures could shed some light on the nature of depositional processes (lodgement vs melt-out) at the glacier sole in this area.

2) Sedimentology of the late Wisconsinan and pre-Wisconsinan alluvium. Sedimentology of fine-grained alluvial sequences in large valleys is poorly understood. Bedding structures are present in these alluvial units in the emergency spillway. Detailed documentation of the structures and interpretation of the depositional environments would greatly enhance the present sketchy picture of their origin. An additional aspect of the alluvial units which needs research is the paleogeographic setting of the deposits. What valley were these deposits associated with and what portion of the valley landscape is represented by these deposits?

3) Refinement of the chronologic position of the pre-Wisconsinan alluvium. At this time data is not available for placing the older alluvium in the exposures any more precisely in time than younger than Pre-Illinoian tills in the Saylorville Lake area and older than the base of the late Wisconsinan loess which buries the older alluvium. More detailed stratigraphic studies and/or thermoluminescence dating of this alluvium could resolve this issue.

4) Study of the paleosols developed into the pre-Wisconsinan alluvium.

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77 SES-1
LOCATION: T80N, R.24W, SEC. 31, NW 1/4

NOTES:

Description of Saylorville Emergency Spillway Sections 1A and 1B.

This section is located on the right bank (southwest side) of the channel cut in the Emergency Spillway for Saylorville Lake (Fig. 2-1). The top of the section is a surface stripped as the original emergency spillway channel floor.

The section consists of two units: 1) a thick, extensive, fine-grained alluvial fill which, on the south end of the excavation, is unconformably overlain by; 2) Late Wisconsinan Des Moines Lobe basal till and associated glaciofluvial deposits (see Fig. 2-12). The two units are described in more detail below.

Late Wisconsinan Des Moines Lobe basal till. This unit is dominated by a massive, matrix-dominated loam diamicton (Dmm). The particle-size disbribution of this diamicton differs from that of 'modal' Des Moines Lobe basal till in two respects: 1) it contains a higher percentage of medium to very large pebble-sized clasts (probably from incorporating relatively "local" bedrock); and 2) it has a noticeably reduced sand content, most likely from incorporating and assimilating substantial amounts of the Wisconsinan loess which constitutes the Des Moines Lobe bed material over much of the Polk, Story, and Boone Counties area. This diamicton is dark gray (N4.5/0), unoxidized and unleached (UU). The upper 30 to 50 cm of the diamicton contains abundant oxidized sub-horizontal joints. There are no deformation features associated with these joints, and thus they may represent modern stress-relief fractures (from previous overburden stripping) rather than subglacial glacitectonic shear planes. At the northwest end of the diamicton exposure is a small channel fill of sand, gravel (coarse sand to medium pebbles) and log fragments that occur between the basal till and the underlying alluvial fill sequence. At the southwest end of the exposure, the basal till is also separated by associated glaciofluvial deposits from the underlying alluvial fill sequence. The glaciofluvial deposits are poorly exposed but appear to thicken and coarsen (from coarse sand to coarse pebbles) towards the southeast. Where the basal till rests directly on the underlying fine-grained alluvial fill sequence, the contact is marked by occasional large pebbled-sized clasts, and there appears to be no disturbed bedding in the alluvial fill sediments.

Wisconsinan Alluvial Fill. This unit consists of laminated to thinly-bedded fine-grained (dominantly silt loam) alluvium with thin (up to 1 cm thick), discontinuous (lenticular), wavy lenses of fine to medium sand; these sands do not delineate any incised channel forms. The unit contains abundant mollusc shells and abundant wood (twigs and branches). On fresh exposure, the alluvium is unoxidized and unleached (UU); the fine-grained sediments are dark gray (N4/0) while the sandy sediments are gray (N 5/0). On a weathered face, the fine-grained sediments appear olive brown, reduced and unleached (RU), while the sands appear oxidized, yellowish brown, and unleached (OU).

77 SES-2
LOCATION: T.80N, R.24W , SEC. 31, NW 1/4

NOTES:

Description of 77 Saylorville Emergency Spillway Section 2.

This section is located on the left bank (northeast side) of the channel cut in the Emergency Spillway for Saylorville Lake (see location on Fig. 2-1).

The top of the section approximates the natural landsurface; the south end of the exposure has been covered by a thin veneer of fill composed predominantly of excavated Pennsylvanian bedrock. Composite sampling and description was made from four sections (2A, 2B, 2C, and 2D; see Fig. 2-3 for location) in order to take advantage of the best exposures.

77 SES-2A and 2B

Depth (cm)	Weathering Zone (Soil Horizon)	Description
		FILL
0 - 46	OL	Fill mixed 10YR and 5YR hue loam, cloddy, friable, noneffervescent, abrupt smooth lower boundary, abundant roots.
		HOLOCENE ALLUVIUM/COLLUVIUM
46 - 56	(E)	Grayish brown (10YR 5/2) silt loam, weak medium platy soil structure, friable, noneffervescent, clear irregular lower boundary, few roots.
56 - 96	(Bt1)	Brown to dark brown (10YR 4/3 - 3/3) loam, moderate medium subangular blocky, friable, noneffervescent, gradual smooth boundary, common thin discontinuous dark brown (10YR 3/3) cutans (secondary clay coatings), common fine well-rounded pebbles.
96 - 156	[2Bt2 (2Ab)]	Very dark grayish brown to dark brown (10YR 3/2 - 3/3) heavy silt loam to loam , strong medium to coarse angular blocky grading to subangular blocky at base of horizon, friable, noneffervescent, clear smooth boundary, abundant fine to medium brown (7.5YR 4/4) mottles, thick continuous dark grayish brown (10YR 4/2) cutans, pebbles as above.

77 SES-2A and 2B (cont'd)
LOCATION: T.80N, R.24W , SEC. 31, NW 1/4

Depth (cm)	Weathering Zone (Soil Horizon)	Description
156 - 176	(2BC)	Brown (10YR 4/3) heavy silt loam, weak to moderate fine subangular blocky, friable, noneffervescent, clear smooth boundary, mottles as above, few thin discontinuous dark brown (10YR 3/3) cutans, few subrounded pebbles.
		WISCONSINAN LOESS
176 - 417	MDU2 (3C1)	Grayish brown and light yellowish brown (2.5Y 5/2 and 6/4) silt loam with occasional 7 to 10cm thick light olive brown (2.5Y 5/4) bands, massive, friable, violent effervescence, abrupt smooth boundary, common coarse mottles of the alternate color, few medium pipestems (secondary iron oxide concretions), common fine oxides, few coarse hard and abundant medium soft carbonate concretions, common gastropod shells.
417 - 470	DU2 (3C2)	Grayish brown (2.5Y 5/2) silt loam, massive, friable, violent effervescence, abrupt smooth boundary, common coarse brown (7.5YR 4/4) mottles, common medium pipestems, abundant fine soft carbonate concretions.

77 SES-2C and 2D

Depth (cm)	Weathering Zone (Soil Horizon)	Description
		HOLOCENE ALLUVIUM AND WISCONSINAN LOESS
0 - 170		Not sampled or described here; see sections 2A and 2B which are lateral to this one.
		PRE-WISCONSINAN ALLUVIUM
170 - 182	(3Eb)	Brown (10YR 5/3) silt loam, weak medium to fine angular blocky, friable, noneffervescent, gradual wavy boundary, abundant fine brown (7.5YR 4/4) mottles, common medium strong brown (7.5YR 5/8) pipestems, common thin discontinuous brown (10YR 4/3) cutans on large columnar units extending from base of modern solum.

77 SES-2C and 2D (Continued)
LOCATION: T.80N, R.24W , SEC. 31, NW 1/4

Depth (cm)	Weathering Zone (Soil Horizon)	Description
182 - 200	(3EBb)	Brown (10YR 5/3) clay loam, moderate fine angular blocky, firm, noneffervescent, gradual smooth boundary, common thin discontinuous grayish brown (10YR 5/2) silans.
200 - 235	(3Btb)	Brown (10YR 4/3) clay loam to silty clay loam, strong medium to fine angular blocky, very firm, noneffervescent, gradual smooth boundary, abundant fine brown (7.5YR 4/4) and medium yellowish brown (10YR 5/8) mottles, thick continuous dark grayish brown (10YR 4/2) cutans.
235 - 275	(3BCb)	Dark yellowish brown (10YR 4/4) clay loam to loam, moderate medium to fine subangular blocky, firm, noneffervescent, gradual smooth boundary, mottles as above, common medium well-rounded pebbles.
275 - 405	MOL (3C1b)	Yellowish brown (10YR 5/6) loam with occasional sandy loam zones, massive to very weak coarse subangular blocky, friable, occasional 10-20cm thick zones of moderate medium angular blocky structure (soils?), noneffervescent, abrupt smooth boundary, abundant medium to coarse grayish brown (10YR 5/2) mottles, common medium oxides.
405 - 418	OL (3C2b)	Reddish brown (5YR 4/3) texturally stratified loam to silty clay loam, massive, firm, noneffervescent, abrupt smooth boundary, abundant fine angular to subrounded clasts of Pennsylvanian sandstone, siltstone and shale in lower 10cm.
418 - 541	MOL (3C3b)	Brown to strong brown (7.5YR 5/4 - 5/6) loam, massive, friable, noneffervescent, abrupt smooth boundary, abundant medium to coarse grayish brown (10YR 5/2) mottles, occasional medium to fine well-rounded pebbles of mixed lithology, unit gets sandier with depth and contains common medium well-rounded to angular pebbles dominated by local Pennsylvanian lithologies.
541 - 583	MOL (3C4b)	Dark grayish brown and brown (10YR 4/2 and 4/3) loam to sand, massive to single grain, friable, noneffervescent, common medium well-rounded pebbles in upper 20cm, common medium yellowish brown (10YR 5/8) mottles, abrupt smooth boundary.

77 SES-2C and 2D (Continued)
LOCATION: T.80N, R.24W , SEC. 31, NW 1/4

Depth (cm)	Weathering Zone (Soil Horizon)	Description
583 - 720	MOL (4C1b)	Brown (7.5YR 4/4) silt loam to loam, massive to very weak medium subangular blocky, firm, noneffervescent, abrupt smooth boundary, common coarse yellowish brown (10YR 5/4) mottles, common medium oxides, abundant medium to fine well-rounded pebbles, 10cm thick zone of matrix supported medium gravel at base of horizon.
720 - 995	DL (4C2b)	Dark grayish brown and grayish brown (10YR 4/2 and 5/2) weakly stratified silt loam grading downward to sandy loam, massive, firm, noneffervescent, common 5 to 10cm thick troughs of matrix supported angular to subangular pebbles dominated by local Pennsylvanian lithologies, 20cm thick trough of clast supported pebbles and cobbles dominated by local Pennsylvanian lithologies but containing several erratic lithologies at base of exposure.

77 SES-10
LOCATION: T80N, R.24W, SEC. 31, NW 1/4

NOTES: Description of 77 Saylorville Emergency Spillway Section 10

This section is located on the right bank (southwest side) of the channel cut in the Emergency Spillway for Saylorville Lake (see location on Fig. 2-1). The top of the section is a surface stripped as the original (pre 1984) emergency spillway channel floor.

The section consists of three major units: 1) a thick sequence of pre-Wisconsinan alluvium overlying Pennsylvanian rock unconformably overlain by; 2) Wisconsinan loess unconformably overlain by; 3) late Wisconsinan Des Moines Lobe basal till.

The pre-Wisconsinan alluvium consists of three distinct units: 1) a basal brown (7.5YR) unit containing occasional troughs filled with medium to fine pebbles and sand. The basal unit is erosionally truncated by a very dark grayish brown (10YR) loam unit surmounted by a buried soil. The middle unit is unconformably overlain by a loamy greenish gray unit surmounted by a morphologically well expressed, poorly drained paleosol. The lower two units of alluvium correspond to the two pre-Wisconsinan alluvial units described at 77 SES 2C and 2D. The Quaternary section rests on a Middle Pennsylvanian Floris Formation limestone.

Depth (cm)	Weathering Zone (Soil Horizon)	Description
		DOWS FORMATION, ALDEN MEMBER
0 - 38	MOJL	Brown to strong brown (7.5YR 5/4 - 5/6) loam, friable to firm, noneffervescent, clear smooth boundary, abundant medium olive yellow (2.5Y 6/6) mottles, common roots, common thin discontinuous very dark grayish brown (10YR 3/2) coatings along joint faces.
38 - 63	MOJL	Yellowish brown (10YR 5/4) loam, weak medium to coarse subangular blocky, firm, noneffervescent, abrupt smooth boundary, common medium brown (7.5YR 4/4) mottles, common subrounded medium pebbles of local Pennsylvanian lithologies, coatings as above.
63 - 83	MOJL	Yellowish brown (10YR 5/4) loam, massive, firm, noneffervescent, abrupt smooth boundary, abundant medium reddish brown (5YR 4/4) mottles, clasts as above, coatings as above.

77 SES-10 (Continued)
LOCATION: T80N, R.24W, SEC. 31, NW 1/4

Depth (cm)	Weathering Zone (Soil Horizon)	Description
83 - 116	MOJL	Light olive brown (2.5YR 5/4) loam, massive, firm, noneffervescent, abrupt smooth boundary, abundant medium dark gray (2.5Y 4/1) mottles, fewer clasts than above, coatings as above.
116 - 143	MOJL	Brown (10YR 5/3) loam, massive, friable, noneffervescent, abrupt smooth boundary, abundant medium brown (7.5YR 4/4) mottles and streaks, contains common medium pebbles dominated by local Pennsylvanian lithologies with occasional erratic lithologies, common 20 X 10cm block inclusions of light brownish gray (10YR 4/2) loam containing abundant discontinuous silans and exhibiting moderate medium platy structure (these may have originally been part of an E horizon destroyed by glacial erosion), coatings as above.
143 - 165	MRL	Olive gray to greenish gray (5Y 5/2 - 5GY 5/1) loam, massive, friable, noneffervescent, abrupt irregular boundary, abundant medium to fine olive gray (2.5Y 5/2) mottles, common medium iron accumulations.
165 - 175	RL	Dark grayish brown (2.5Y 4/2) loam, massive, friable, noneffervescent, abrupt irregular boundary, common medium to fine iron accumulations, common charcoal flecks, common blobs and streaks of E horizon material similar to 116-143, occasional medium to coarse pebbles of mixed lithology.
		WISCONSINAN LOESS
175 - 295	DU	Grayish brown (2.5Y 5/2) silt loam, massive, friable, weak to moderate effervescence, clear smooth boundary, few dark gray (2.5Y 4/1) streaks, common gastropod shells.
295 - 379	UJL	Dark greenish gray (5GY 4/1) silt loam, massive, friable, noneffervescent, abrupt smooth boundary, common organic smudges in lower 37cm, yellowish brown (10YR 5/4) oxidation rind along joints.

77 SES-10 (Continued)
LOCATION: T80N, R.24W, SEC. 31, NW 1/4

Depth (cm)	Weathering Zone (Soil Horizon)	Description
		PRE-WISCONSINAN ALLUVIUM
379 - 393	(3Ab)	Dark gray (5Y 4/1) clay loam, moderate fine angular blocky, friable, noneffervescent, clear wavy boundary, common medium dark greenish gray (5GY 4/1) mottles.
393 - 412	(3Bg1b)	Dark greenish gray (5GY 4/1) clay loam, moderate fine angular blocky, friable, noneffervescent, clear smooth boundary, common coarse dark greenish gray (5G 4/1) mottles, common slickensides.
412 - 424	(3Bg2b)	Dark greenish gray (5GY 4/1 - 5G 4/1) clay loam, moderate fine angular blocky, friable, noneffervescent, gradual smooth boundary, common coarse greenish gray (5G 5/1) mottles, slickensides as above, common fine well-rounded pebbles of mixed lithology.
424 - 451	(3Bg3b)	Dark greenish gray (5G 4/1) silty clay and silty clay loam, strong medium to fine angular blocky, friable, noneffervescent, gradual smooth boundary, few coarse greenish gray (5G 5/1) mottles.
451 - 467	(3Bg4b)	Dark greenish gray (5GY 4/1) silty clay loam, moderate fine angular blocky, friable, nonffervescent, clear smooth boundary, common medium greenish gray (5G 5/1) mottles.
467 - 480	MRL (3Cg1)	Dark greenish gray and greenish gray (5BG 4/1 and 5/1) silty clay loam, massive, friable, noneffervescent, abrupt irregular boundary, few fine greenish gray (5GY 5/1) mottles.
480 - 506	MRL (3Cg2)	Dark gray (5Y 4/1) loam, massive, friable, noneffervescent, clear smooth boundary, abundant medium to coarse greenish gray (5G 5/1) mottles, occasional well-rounded fine pebbles of mixed lithology.
506 - 551	RL (3Cg3)	Dark gray and dark greenish gray (5Y 4/1 and 5G 4/1) stratified loam and fine to medium sand, massive to single grain, friable to loose, noneffervescent, abrupt boundary, occasional well- rounded fine to medium pebbles of mixed lithology.

77 SES-10 (Continued)
LOCATION: T80N, R.24W, SEC. 31, NW 1/4

Depth (cm)	Weathering Zone (Soil Horizon)	Description
		PRE-WISCONSINAN ALLUVIUM
551 - 590	(4ACb)	Very dark grayish brown (10YR 3/2) silt loam, very weak medium subangular blocky, friable, noneffervescent, abrupt wavy boundary, few fine greenish gray (5GY 5/1) mottles, brown (7.5YR 4/4) staining along joint faces.
590 - 605	MOJL (4C1)	Very dark grayish brown (10YR 3/2) stratified silt loam, medium sand and matrix supported subrounded fine pebbles dominated by local Pennsylvanian lithologies, friable, noneffervescent, abrupt smooth boundary, common fine greenish gray (5GY 5/1) mottles, stains along joint faces as above.
605 - 620	OL (4C2)	Very dark grayish brown (10YR 3/2) loam, massive, friable, noneffervescent, abrupt smooth boundary, occasional subrounded medium to fine pebbles of local Pennsylvanian lithology.
		PRE-WISCONSINAN ALLUVIUM
620 - 628	OL (5C1)	Brown (7.5YR 4/4) sandy loam, massive, friable, noneffervescent, abrupt smooth boundary.
628 - 649	MRJL (5C2)	Dark gray (10YR 4/1) silt loam, massive, friable, noneffervescent, abrupt smooth boundary, common disrupted (burrowed?) pale brown (10YR 6/3) planar silt loam beds, brown (7.5YR 4/4) staining along joints.
649 - 654	OL (5C3)	Brown (7.5YR 4/4) loam, massive, friable, noneffervescent, abrupt smooth boundary, occasional fine to medium subrounded pebbles dominated by local Pennsylvanian lithologies.
654 - 679	MRJL (5C4)	Same as 628-649.
679 - 688	OJL (5C5)	Same as 620-628 with stains along joints as above.

77 SES-10 (Continued)
LOCATION: T80N, R.24W, SEC. 31, NW 1/4

Depth (cm)	Weathering Zone (Soil Horizon)	Description
688 - 988	RJL (5C6)	Very dark gray to very dark grayish brown (10YR 3/1 - 3/2) loam to silt loam, massive, friable, noneffervescent, occasional 7-10cm thick troughs of matrix supported subrounded medium to fine pebbles dominated by local Pennsylvanian lithologies, stains along joints as above.

PART 3. PRELIMINARY REPORT ON THE QUATERNARY PLANT RECORD FROM THE SAYORVILLE EMERGENCY SPILLWAY

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Introduction and Methods

The fine grained, late Wisconsinan-age alluvial sequence at Section O was sampled for pollen, plant macrofossils, and insects by Dr. Donald P. Schwert (North Dakota State University) and myself. Only the work on the plant macrofossils has been completed to date. The sediments were washed through 0.5 - and 0.1 mm screens and plant macrofossils were picked from the residue. The macrofossils were identified by comparison with the University of Iowa Seed and Fruit Collection, Department of Geology. Results are shown on Table 3-1.

Pollen samples have been processed with standard KOH, HCI, HF, and acetolysis treatments. *Eucalyptus* pollen was added in tablets to allow calculation of pollen concentration. Most samples are very poor in pollen, however some slides may be countable.

Two radiocarbon dates were obtained from Section O. A date of 13, 160 ±150 yr. B.P. (Beta 10835) comes from wood just below the Des Moines Lobe till. The second date is 15,290 ±110 yr. B.P. (Beta 10836) on wood from 70-80 cm above the base of the section (Fig. 2-6, Bettis et al., this volume).

Results

Reported elevations are measured from the base of the exposed section upward. All samples have abundant *Carex* (sedge) fruits, with peak numbers at 40-60 cm (Table 3-1). The bottom samples (0 -70 cm) are poor in macrofossils generally, and they contain only a few specimens of arboreal plants (spruce needles). From 80 to 180 cm arboreal macrofossils are more abundant, and *Larix* (larch), *Salix* (willow), and *Populus* (poplar) were also present at times during this interval. Another interval of few fossils occurs between about 180 and 240 cm, and above 240, *Picea* (spruce) needles again become extremely abundant.

Without pollen analysis to accompany the plant macrofossils, it is difficult to interpret the results unequivocally. Clearly though, the area was dominated by sedges, and it was probably a wetland environment. *Betula glandulosa* (bog birch), *Picea* (spruce), *Larix* (larch) *Salix* (willow), and *Glyceria* (manna-grass) all grow in wetland environments as well. The occasional presence of *Potamogeton* (pondweed) suggests that open water was present at times. Weedy disturbance plants like *Chenopodium* (goosefoot) and *Mollugo verticillata* (carpetweed) indicate that disturbed ground was present during one interval. The assemblage suggests that an extensive fen or marsh was present.

The scarce arboreal macrofossils below 70 cm and their abundance above could be explained in several ways. One hypothesis might be that trees were scarce and the environment was fairly open about 15,000 yrs. B.P. during the early phases of deposition at the site, and that a more closed forest predominated during the middle and later phases. Another possibility is that trees were present in the region, but that they were absent right at the site; because of the local distribution of macrofossils, they do not appear in these sediments. These problems cannot be resolved without further data.

The presence of boreal taxa like spruce, larch, and bog birch suggests that conditions were much cooler than at the present, but that they were not so cold that tundra was present.

References

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Table 3-1

Saylorville Reservoir spillway macrofossils
Collected by D. Schwert and R.Baker

Levels	needles	Picea twigs	seeds	Larix needles	Salix bd scls	Populus bd scls	Carex biconvex	Carex trigonous	Carex rostrata	Carex diandra	Chenopodium seeds	Mollugo seeds	Potentilla seeds	Glyceria
329-352 (top)	yes		yes				yes							
280-300	>1000	1				1	91	2						
240-260	243		1				79	4						
220-240	75				1?		38							
200-220	32				1		18							
180-200	37						16	2.5						
160-180	139		2				10	1						16
140-160	yes						yes							
120-140	127	1		24			15	2.5	3					
100-120	36		2	2		11	14							
90-100	62			2		25	16	1						
80-90	119	2	3	17	1		57		1		4	1	1	
60-70	yes				1		15	1						
50-60	1						147							
40-50							155							
30-40	4						58							
20-30	3						26							
10-20							54							
0-10 (bottom)	2		yes				yes	yes		yes?				

Levels	Crucifer	Betula gland.	Potamogeton	mosses	mollusc	insects	grass caryopsis
329-352 (top)				many		yes	
280-300			1	many	9	yes	
240-260		2	1	yes	7	12	
220-240		2		yes		3	
200-220				yes	4	2	
180-200				2	many	3	
160-180				yes	many	8	1
140-160				yes	yes		
120-140				yes	yes	yes	
100-120		?		yes	yes	yes	
90-100			1	yes	yes		1
80-90				yes	many	4	
60-70				yes	many	1	
50-60		1			6	4	
40-50	1				3.5	6	
30-40				3	2	yes	
20-30				2	1	yes	
10-20					1	yes	
0-10 (bottom)				yes		yes	

PART 4. PRELIMINARY REPORT ON QUATERNARY MOLLUSCS FROM THE SAYLORVILLE EMERGENCY SPILLWAY

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Introduction and Methods

Four samples of molluscs from two different stratigraphic units exposed in the Saylorville Emergency Spillway were studied. One sample (SES-2 Lower, Table 4-1) was from Wisconsinan-age loess exposed at Section 2 (Fig. 2-3, Bettis et al., this volume). The other three samples (Table 4-1) were from late Wisconsinan-age alluvium. Two of these samples (SES-1 Upper, SES-1 Lower) were from Section 1 (Fig. 2-12, Bettis et al., this volume), and one sampel (SR) was a composite sample from the plant macrofossil sampling at Section 0 (Baker, this volume). Molluscs are a common component of the fauna in all four samples. In the Wisconsinan-age loess (SES-2 Lower) the molluscs were evenly distributed throughout the deposit. In the late Wisconsinan-age alluvium the molluscs were concentrated in thin beds of limited lateral and vertical extent.

To isolate the molluscs for study, bulk samples were partially dried, disaggregated through the use of detergents, and washed through a series of sieves. The smallest screen mesh used was Tyler Standard sieve 35 (0.425 mm). For the Wisconsinan loess sample (SES-2 Lower) an approximately 15 kg sample of sediment containing molluscs was available for study and about 200 specimens were recovered. Fifteen kg samples were also available from each of the two late Wisconsinan-age alluvium samples at Section 1 (samples SES-1 Upper, SES-1 Lower). Roughly 500 specimens were contained in each of these samples. In the remaining sample of late-Wisconsinan alluvium (sample SR from Section 0), approximately 80 specimens total were obtained from a composite of all levels. The molluscs obtained for this sample were a by-product of detailed stratigraphic sampling for pollen and spores, plant macrofossils, and insects. For the details of sample processing at this site see Baker, this volume. Samples from each studied interval at this site were generally much smaller than is standard for bulk samples collected for molluscs. Because it is quite possible that 95% of the original total diversity is not present in the sample (SR), inferences as to site environment based on mollusc associations are regarded as tentative. It is also possible that 95% of the original total diversity is not present in the small sample (200 specimens) of the Wisconsinan-age loess (sample SES-2 Lower) and the paleoenvironmental interpretation for this sample should likewise be regarded as tentative.

Results

A faunal list and interpretation of provincial affinities are given respectively in Tables 4-1 and 4-2. The following sections discuss the fauna

TABLE 4-1. Saylorville Mollusca.*

	SR	UNIT SES-1 LOWER	SES-1 UPPER	SES-2 LOWER
Terrestrial Gastropoda:				
Oreohelix strigosa cooperi	-	-	-	x
Triodopsis multilineata	-	x	x	-
Mesodon clausus	-	x	x	-
Nesovitrea electrina	x	x	x	-
Stenotrema leai	x	-	-	-
Hendersonia occulta	x	x	x	-
Discus cronkheitei	x	x	x	x
D. shimeki	-	x	-	x
Deroceras laeve	x	-	x	-
Euconulus fulvus	-	x	x	x
Carychium exiguum	x	x	x	-
Columella alticola	x	x	x	x
Vertigo modesta modesta	-	x	x	x
V. modesta parietalis	-	-	-	x
V. elatior	x	x	x	x
V. alpestris oughtoni	-	x	-	x
Pupilla muscorum	x	x	x	x
Vallonia gracilicosta	x	x	x	x
Succinea bakeri	x	x	x	x
Catinella avara	x	x	x	x
C. gelida	x	x	x	x
Oxyloma sp.	-	x	-	-
Aquatic Gastropoda:				
Valvata sincera	-	x	-	-
Fossaria (Fossaria) exigua	x	x	x	-
F. (F.) parva	x	x	x	-
Physella (Phsella) gyrina gyrina	x	-	-	-
Gyraulus (Torquis) parvus	x	-	-	-
Aquatic Pelecypoda:				
Pisidium nitidum	x	x	-	-

* Samples SR, SES-1 Lower, and SES-1 Upper are from late Wisconsinan-age alluvium. Sample SES-2 Lower is from Wisconsinan-age loess.

TABLE 4-2. Provincial affinities of Saylorville land snails.

SPECIES	PROVINCE	MODERN OCCURRENCE IN IOWA
Oreohelix strigosa cooperi	R	-
Triodopsis multilineata	I	x
Mesodon clausus	I	x
Nesovitrea electrina	C	x
Stenotrema Leai	C	x
Hendersonia occulta	E	r
Discus cronkheitei	C	x
D. shimeki	R	-
Deroceras laeve	C	x
Euconulus fulvus	C	x
Carychium exiguum	C	x
Columella alticola	R,?N	r
Vertigo modesta modesta	R,N	-
V. modesta parietalis	N	-
V. elation	N	r
V. Alpestris oughtoni	N	-
Pupilla muscorum	N	-
Vallonia gracilicosta	R	r
Succinea bakeri	E	-
Catinella avara	C	x
C. gelida	E	t
Oxyloma sp.	-	-

Provincial affinities: R - Rocky Mountain; I - Interior; N - Northern; C - cosmopolitan; occurs in two or more modern provinces; E - extinct or Pleistocene relict taxon, no modern counterpart.

Occurrence: x - present in Iowa, widely distributed; r - present as relict taxon only, very limited modern distribution.

and interpreted paleoenvironments of the Wisconsinan-age loess and late Wisconsinan-age alluvium.

Wisconsinan-age Loess

The loess has an entirely terrestrial fauna which consists of 13 land species. The fauna is a typical upland, somewhat xeric (low moisture) assemblage bearing a close resemblance to most late Wisconsinan loess localities in Polk County. The fauna is strongly disharmonious in comparison to modern distribution patterns, a common trait of most Midwestern loess sites (Table 4-2). Many common taxa are widely distributed in modern North America. Of those more strongly endemic, Northern and Rocky Mountain forms are prominent and common, but Interior endemics are essentially absent. The modern land snail fauna of Polk County comprises some 40 taxa, all either cosmopolitan or Interior endemics. Disregarding the extinct or relict forms, the fauna most closely resembles that of the modern taiga. Species diversity is higher than in Wisconsinan tundra analogues, and several larger taxa, generally absent from tundra environments, are present in small numbers. No obligate deciduous tree feeding species are noted, and the extinct or relict component is small, with no suggestion of Midwest Biome affinities. Occurrence of *Oreohelix* and the relatively high diversity for a taiga-like site indicates the presence of some open ground in a landscape dominated by coniferous forests similar to that presently found in southern Manitoba, central and southern Ontario, and northern Minnesota.

Late Wisconsinan-age Alluvium

Despite somewhat differing ages, the three samples of late Wisconsinan-age alluvium have broadly similar faunas and will be discussed together. All three samples have a preponderance of land snails. In comparison to the loess fauna (SES-2 Lower), the late Wisconsinan-age alluvium has higher diversity (18-21 species) and a distinct aquatic component (Table 4-1). The amphibious species *Fossaria exigua* and *Fossaria parva* are common to all samples. The fully aquatic taxa are represented by one or two specimens only, and they are not common to all of the samples (Table 4-1). This suggests a very moist habitat, albeit with little standing water at the site itself. Overall aquatic diversity is low, and all species are currently widely distributed in northern and central North America. Open-water forms are particularly rare (e.g., *V. sincera)* and may represent waifs from a nearby more permanently water-covered area. Occurrence of most specimens in narrow, concentrated beds suggests seasonal or storm-related swashes. The dominance of land taxa in all three samples indicates that the beds are not shoreline debris but that they might have accumulated closer to the base of an adjoining slope rather than the shore of a standing water body. This interpretation is supported by the relative scarcity and low diversity of both ostracods and beetles which are very rare in all three alluvium samples. The diverse land fauna suggests transport from upland environments, but the rarity of full aquatics suggests relatively little input from the inferred full aquatic habitat some distance from the sample site. However, differences in land snail species composition between the loess site and the alluvium demonstrate that transport from the upland habitat is minor. Large taxa are common in both the loess and late Wisconsinan-age aluvium, but the species are different. Small taxa in the loess which prefer more xeric habitats are quite rare in the late Wisconsinan-age alluvium. The additional land taxa in the three alluvium samples are all moisture-loving species quite common today on relatively level lowland sites, such as floodplains or moist areas adjacent to swamps and marshes throughout much of southern Canada and the north and central parts of the United States.

Despite the abundance of spruce macrofossils in the late Wisconsinan-age alluvium, none of the land snails so far identified are obligate forest dwellers, and the majority are most common in a variety of open-ground, herb-and sedge-dominated environments. Among the land snails, the Northern and Rocky Mountain components are still prominent, but a few taxa more characteristic of the present Interior molluscan province (*Triodopsis multilineata*, *Mesodon clausus* and *Carychium exiguum*) are added. These sample sites thus appear to represent a more sheltered microhabitat, probably slightly warmer as well as much less xeric in aspect as compared to that during earlier loess deposition. This interpretation is also consistent with field relationships which indicate that the late Wisconsinan-age alluvium is incised into, and thus younger than, the Wisconsinan loess at this site (Bettis et al., this volume).

The preponderance of widely distributed and ecologically broadly tolerant species in terms of abundance, together with the moderate species diversity, may indicate a relative lack of habitat diversity in the alluvial sites. Collectively the mollusc faunas suggest a relatively open area with a differentiated, relatively high upland and nearly level, moist slope base, with permanent water nearby. Both upland and lowland areas were likely vegetation-covered in part, with herbs and sedges most common, but also with sizeable coniferous stands in the near vicinity. No exact modern analogue is available, but the climate of the southern reaches of the modern taiga (e.g., southern Manitoba, central and southern Ontario, and northern Minnesota) is perhaps most closely comparable. Both upland and lowland habitats were likely contemporaneous, at least in part, and both seem to have persisted unchanged for a significant time period; no abrupt climatic change is evident, and the lowland samples of late Wisconsinan-age alluvium (SR, SES-1 Upper, SES-1 Lower) have closely similar faunas, with differences between SR and SES-1 most likely attributable solely to differences in sample size. Not enough specimens were available from the various levels of the SR site at Section 0 to validate comparisons with the differences in floral macrofossils noted by Baker (this volume).

References

Baker, R.G., this volume, Part 3. Preliminary report on the Quaternary plant record from the Saylorville Emergency Spillway, p. 3-1 to 3-3.

Bettis, A. III, Kemmis, T., Quade, D., Littke, J., this volume, Part 2. The Quaternary deposits of the Saylorville Emergency Spillway, p. 2-1 to 2-42.

PART 5: CLAY MINERALOGY OF THE DOWS FORMATION IN THE SAYLORVILLE EMERGENCY SPILLWAY EXPOSURES

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Introduction

Basal till deposits in the Midwest, such as the Alden Member of the Dows Formation (Des Moines Lobe deposits), generally exhibit remarkable uniformity in matrix properties, often showing little variation over hundreds of square kilometers (Kemmis et al., 1981; Hallberg et al., 1980). One type of exception to this uniformity is commonly encountered near the base of an individual till sheet where the till unit will show evidence of inclusions of the local substrate. These inclusions may be readily recognizable features such as block inclusions, smears, or smudges of the substrate materials (Fig. 6-1, for example), or if these inclusions are thoroughly mixed into till, they may only be recognized by lab analyses which reveal atypical properties, exhibiting a mix of the typical till unit properties and those of the substrate (Kemmis et al., 1981; Hallberg et al., 1980; 1984).

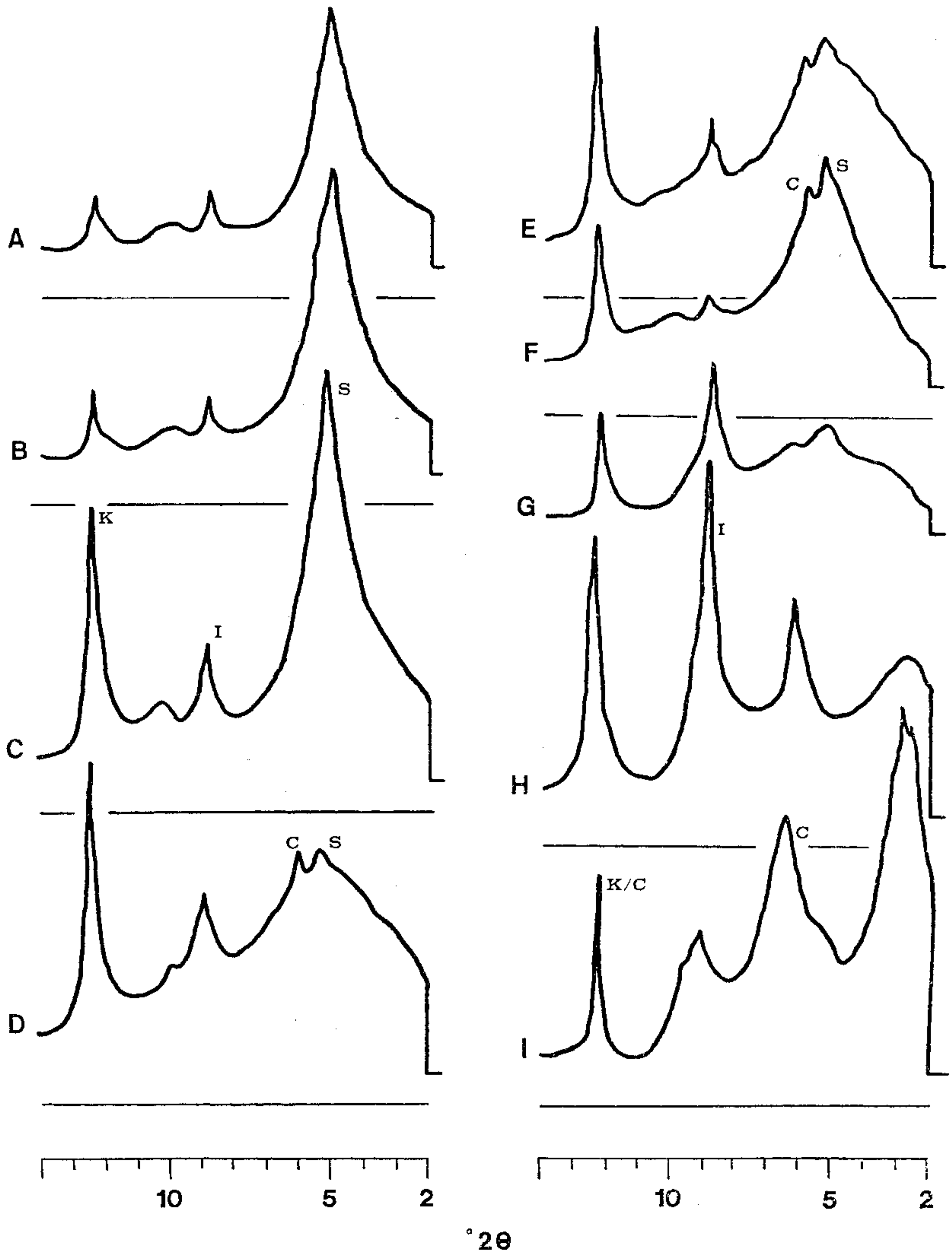
The high elevation of the bedrock surface in the Saylorville area likely promoted compressive flow conditions during the advance of the Des Moines lobe ice. This in turn likely prompted significant subglacial erosion, which may be inferred from the abundant evidence of inclusions of the Pennsylvanian bedrock in the Dows Formation till in this area. Such inclusions are noted at the field trip stops and in the section descriptions and figures. The thorough incorporation of Pennsylvanian rocks into the matrix of the Dows Formation till (Alden Member) can also be seen in the unusual textures and clay mineralogy in many of the sections.

Clay Mineralogy

Figure 5-1 shows a series of smoothed x-ray diffractograms of the <2μm size fraction from glycolated samples (see Hallberg, ed., 1978, for methods). The diffractograms show the x-ray diffraction patterns between 2 and 14 degrees 2-theta, showing the clay-mineral suite of various samples from the field trip area. Various clay mineral peaks are identified by letter: s-smectite 001 (montmorillonite); c-chlorite 001; i-illite 001; k-kaolinite 001; k/c-kaolinite 001 and chlorite 002.

Traces A-C are typical x-ray patterns from: A-Dows Formation, Alden Member; B-Wisconsinan loess; and C-Wolf Creek Formation (Pre-Illinoian age) till. The traces show sharply defined, well-crystallized smectite, illite, and kaolinite peaks. By the semi-quantitative methods used at IGS, the Dows Formation deposits average 69% smectite, 19% illite, and 12% kaolinite. The loess is similar in composition, and the Wolf Creek Formation deposits average 60% smectite, 17% illite, and 23% kaolinite. Some of these differences are visually apparent on Figure 5-1. The incorporation of local substrate

Figure 5-1. Smoothed x-ray diffractograms of glycolated clay mineral samples from the field trip sections. A-typical Dows Formation, Alden Member till; B-typical Wisconsinan loess; C-typical Wolf Creek Formation till; D-fine-grained pre-Wisconsinan alluvium at the Saylorville Emergency Spillway, showing inclusion of Pennsylvanian lithologies; E and F-Dows Formation, Alden Member till from the Saylorville Emergency Spillway showing alteration from the incorporation of Pennsylvanian lithologies; G-smudge of Pennsylvanian mudstone within the Alden Member at the Acorn Valley Section; H and I-Pennsylvanian shale from the Swede Hollow Fm. and a mudstone from the Floris Fm., respectively, exposed at the Saylorville Emergency Spillway. S-smectite, C-chlorite; I-illite; K-kaolinite.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materials often is apparent in quantitative differences, but should also be visibly apparent on Figure 5-1.

Traces H and I are typical of the x-ray patterns from Pennsylvanian-age mudstones, clays, and shales in the area. The samples are from a shale in the Swede Hollow Formation and a mudstone in the Floris Formation, respectively. Neither sample has any smectite (or'expandable') clay-mineral peak. Both show a strong chlorite peak (other work has determined that these are chlorite and not vermiculite peaks, in general), and strong illite and kaolinite peaks of varying intensity.

Traces E, F, and G are Dows Formation, Alden Member samples that exhibit alterations from their typical composition, e.g., trace A. We interpret these alterations to be the result of the abundant inclusions of Pennsylvanian mudstones into the matrix of the till. Trace G is actually a 'smudge' of Pennsylvanian mudstone from the Acorn Valley Section (Fig. 6-1). The smudge has been partially incorporated into the matrix of the till but is still recognizable as a thin sheared mass (smudge) of a Pennsylvanian lithology. Note that trace G shows a small smectite peak which merges with a chlorite peak, and well-defined illite and kaolinite peaks. Traces E and F are from Alden Member till samples at the emergency spillway that had no obvious signs of such sheared inclusions. Still the effect of the incorporation of the Pennsylvanian clays is apparent in the x-ray traces when compared with trace A from the same stratigraphic unit outside the area. In E and F the smectite peak is broadened because of the interference with the chlorite peak, and the illite and kaolinite peaks are uncharacteristically high for Dows Formation deposits.

Trace D is from the fine-grained pre-Wisconsinan alluvium in the emergency spillway. Generally, fine-grained Quaternary alluvium show clay mineral suites similar to traces A through C. Trace D again shows the effect of the incorporation of local Pennsylvanian bedrock lithologies.

Significance

These abberations in the matrix mineralogy are interesting to note, and imply some things about the nature of subglacial erosion in the area. However, the most significant point to be made is that in some areas where subglacial erosion is important, particularly where the local substrate is comprised of soft, incompetent rocks, the matrix properties of till units may be seriously altered from their regional norms because of incorporation of local substrata. This may render many properties we normally measure useless for the purpose of characterization and correlation. Thus, it is imperative that we use as many tools as possible in defining and correlating our stratigraphic units.

References

Hallberg, G.R., 1978, ed., Standard procedures for evaluation of Quaternary materials in Iowa: *Iowa Geol. Surv. Tech. Info. Ser.,* No. 8, 109 p.

Hallberg, G.R., Wollenhaupt, N.C., and Wickham, J.T., 1980, Pre-Wisconsinan stratigraphy in southeast Iowa, *in* Hallberg, G.R., ed.: *Illinoian and Pre-Illinoian stratigraphy of southeast Iowa and adjacent Illinois,* Iowa Geol. Surv. Tech. Info. Ser., No. 11, p. 1-110.

Hallberg, G.R. et al., 1984, The Overburden: Quaternary stratigraphy of Conklin Quarry: *in* Underburden-Overburden: an examination of Paleozoic and Quaternary strata at the Conklin Quarry near Iowa City, Geol. Soc. Iowa Guidebook, No. 41, p. 25-62.

Kemmis, T.J., Hallberg, G.R., and Lutenegger, A.J., 1981, Depositional environments of glacial sediments and landforms on the Des Moines Lobe, Iowa, *Iowa Geol. Surv. Guidebook Ser.,* No. 6, 138 p.

PART 6. STOP 2: QUATERNARY GEOLOGY OF THE ACORN VALLEY SECTION

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Objectives

At this stop there are four aspects of the stratigraphy that we want to focus upon:

1. The nature of a 'typical' Quaternary upland stratigraphic sequence for this area, which contrasts with the valley sequence preserved in the Saylorville Emergency Spillway.
2. Depositional environments and processes of the Des Moines Lobe glacial deposits at this site.
3. The nature of hillslope erosion surfaces, particularly those developed on glacial tills.
4. The sedimentation and pedologic characteristics of a 'Late Sangamon' Paleosol (buried soil).

Overview of the Section

The Acorn Valley Section is located in the SW 1/4 of section 13, T.80N., R.25W., Polk Co., Iowa along an eroded nose slope on the west side of Saylorville Lake. The exposure is a wave-cut scarp created during high water levels in 1984.

As at the Saylorville Emergency Spillway, the Quaternary deposits are preserved in a bedrock valley cut into Pennsylvanian-age bedrock. Unlike the Quaternary deposits at the Saylorville Emergency Spillway, however, the Quaternary sequence preserved here is dominated by upland deposits, rather than by fluvial deposits as at the emergency spillway.

The Quaternary sequence at the described section is typical of that found in the southern portions of the Des Moines Lobe in central Iowa: late Wisconsinan-age Des Moines Lobe glacial deposits (basal till and associated deposits) overlying Wisconsinan-age loess which in turn buries a 'Late Sangamon' erosion surface and paleosol developed in Pre-Illinoian age glacial deposits of the Wolf Creek Formation (Fig. 6-1). The following sections describe the nature of the various stratigraphic units.

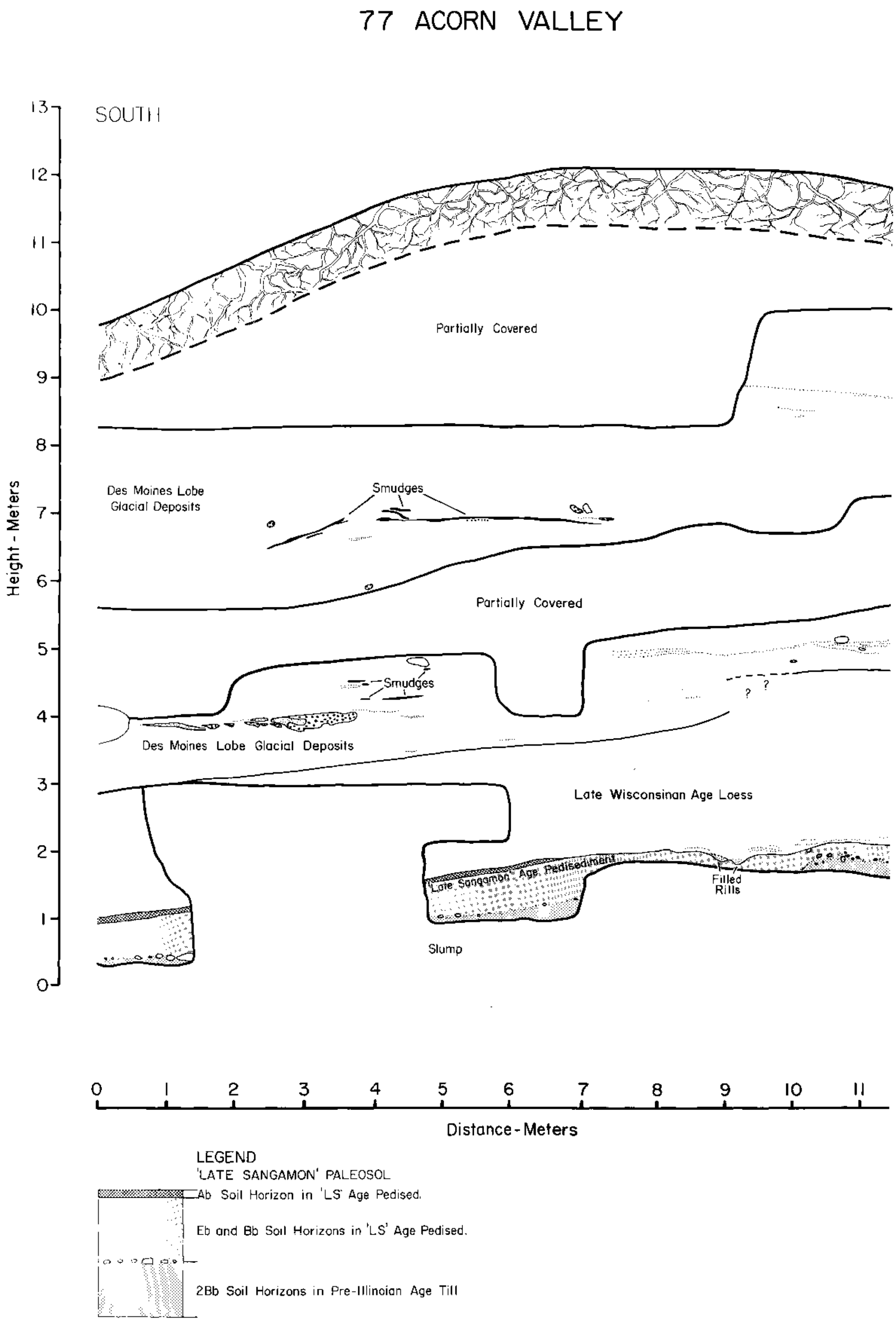
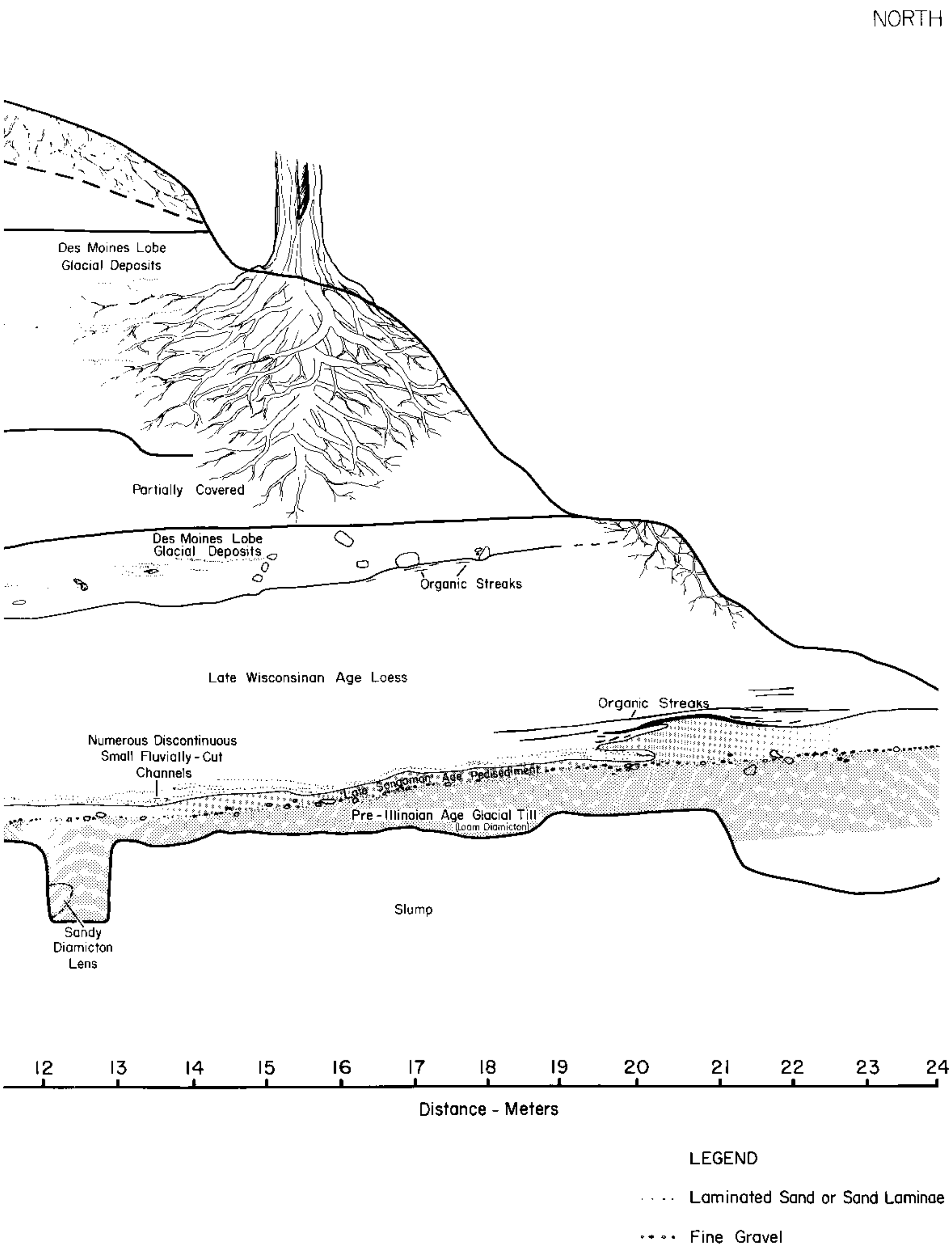


Figure 6-1. Detailed cross-section of the exposure of the Acorn Valley Section.

77 ACORN VALLEY



Description of the Individual Stratigraphic Units

Late Wisconsinan-Age Glacigenic Deposits (Des Moines Lobe deposits)

General. Des Moines Lobe glacial deposits form the uppermost Quaternary stratigraphic unit across uplands throughout the area. Subaerial erosion associated with development of the Des Moines River valley has truncated the upper surface of the Des Moines Lobe deposits at the Acorn Valley Section. Comparison of elevations from the top of the interfluve at Acorn Valley with the adjacent drainage divide between the Des Moines River and Beaver Creek valleys suggests that 15 to 20 m (50 to 60 ft) of Des Moines Lobe deposits have been eroded from the section.

The Des Moines Lobe glacial deposits partially infill a bedrock valley on the Pennsylvanian surface. These general stratigraphic relations can be seen by standing on the lake shore and looking north along adjacent truncated nose slopes. Two hundred to three hundred meters north of the section, Des Moines Lobe deposits lie directly on nearly flat-lying Pennsylvanian-age bedrock. Proceeding south towards the Acorn Valley Section, the base of the Des Moines Lobe deposits dips gently into a bedrock valley, progressively overlying truncated Wisconsinan-age loess and Pre-Illinoian age glacial deposits that are preserved only in the lower portions of the bedrock valley. The gentle southward dip along the base of the Des Moines Lobe deposits can be seen in the sketch of the section (Fig. 6-1).

Primary Properties. The Des Moines Lobe deposits consist predominantly of diamicton deposits at this section. Thin interbedded, sub-horizontal, discontinuous lenses of sand and fine gravel are common in the diamicton as are thin streaked-out 'smudges' (Krüger, 1979) of Pennsylvanian-age bedrock and Wisconsinan-age loess.

The base of the Des Moines Lobe deposits at the described section is on loess. The lower 0.5 m (1 to 1.5 ft) of the Des Moines Lobe diamicton has a significantly siltier matrix (Fig. 6-2) and noticeably fewer and finer pebbles, presumably because of dilution resulting from the glacial erosion and incorporation of underlying loess into the diamicton. The contact between the loess and the overlying diamicton is generally abrupt and can be picked out in the field by the abrupt occurrence of occasional fine pebbles in the diamicton matrix. However, between the distance marks of 9 and 10 meters (Fig. 6-1) the basal diamicton contact could not be placed with confidence. The boundary area there is gradational, and the massive, fine-grained matrix of both the loess and the diamicton made it impossible to pick out the boundary or any deformation structures that might occur at the boundary.

The matrix texture of the diamicton shows some variability (Fig. 6-2). As mentioned earlier, the lower half meter is silty, suggesting incorporation of underlying loess. The variability upwards may reflect the upglacier incorporation of various local source materials (truncation of deposits orginally on the bedrock high up-glacier, for instance; Wisconsinan loess and at least one Pre-Illinoian till unit have been stripped). Some of the incorporation includes smudges of Pennsylvanian-age bedrock and block inclusions of loess. Overall, the diamicton matrix textures, like those in the Saylorville Emergency Spillway, are higher in silt content and lower in sand content than those of basal tills found farther north in the central portion of the Des

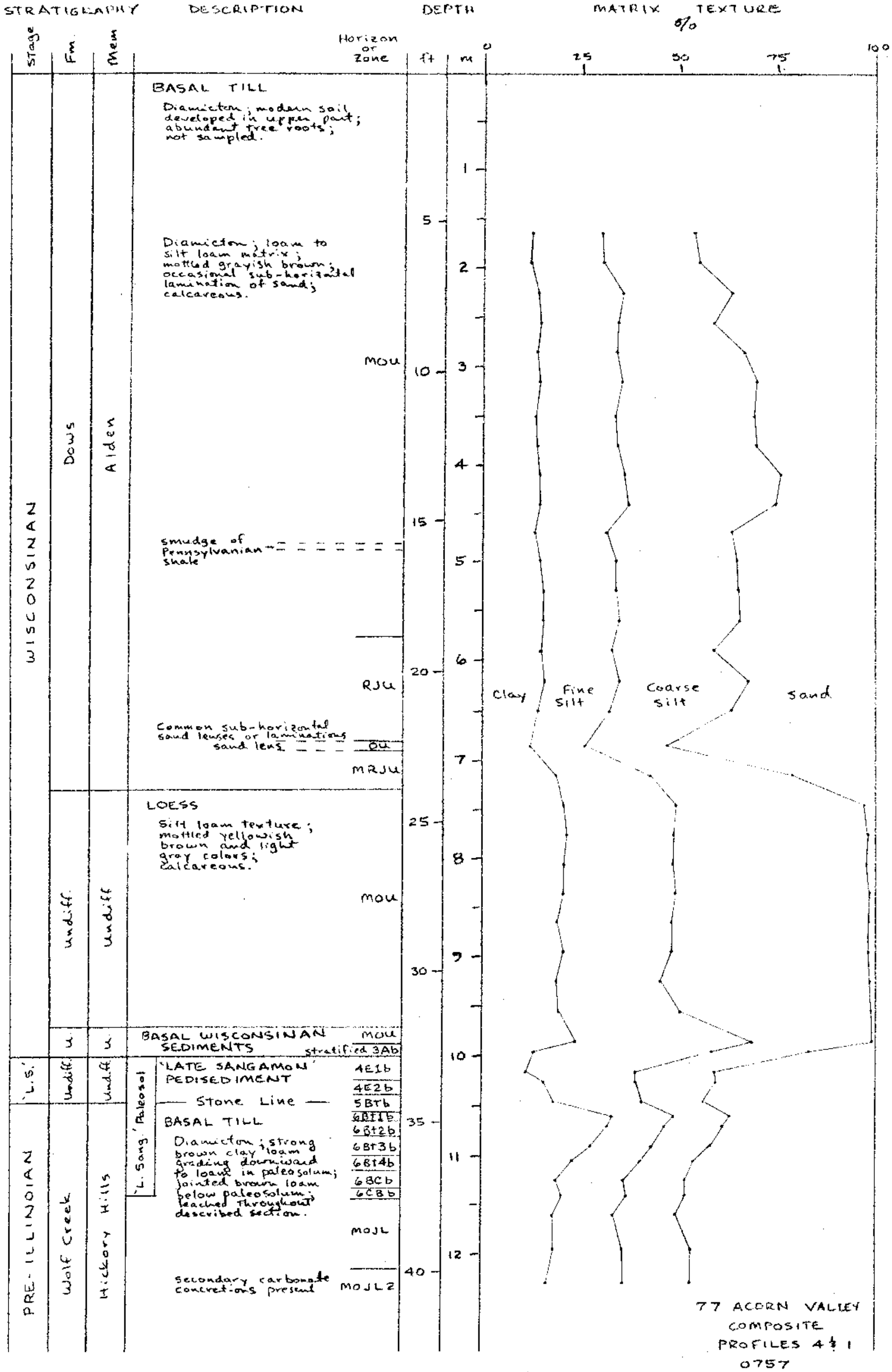


Figure 6-2. Stratigraphy and particle-size of profiles 4 and 1, Acorn Valley Section.

Moines Lobe (Kemmis et al., 1981). The higher silt content results from the incorporation of Wisconsinan loess, which is the dominant sub-Des Moines Lobe bed material from about Ames south (Kemmis and Lutenegger, unpubl.).

Discontinuous, sub-horizontal lenses of sand and gravel are commonly interbedded in the Des Moines Lobe diamicton at Acorn Valley. These lenses are sub-parallel and sub-horizontal. The absence of faulting and various collapse structures suggest that these sediments were deposited subglacially, on a stable substrate, rather than on or in an unstable ice mass which subsequently wasted away. The majority of the lenses are thin, almost lamination-like, within the diamicton mass (Fig. 6-1). A few of the lenses are small-scale channel fills incised into the underlying diamicton (see Fig. 6-1 along the distance marks of 1 to 4 meters at a height of 4 meters). The tops of these channel fills are sub-horizontal and may have been truncated by glacial shear. Such shear-truncated meltwater deposits have been associated with lodgement processes (Krüger, 1979; Eyles et al., 1982; among many others) in the overlying diamicton. Though such shear-related features indicate actively moving ice, diamicton deposition occurs subsequently. Deposition could be by lodgement, but there is no reason why the ice could not have stagnated and the basal debris melted-out passively as melt-out till either.

Smudges (Krüger, 1979), thin, discontinuous, streaked-out lenses of Pennsylvanian-age shales and similar streaked-out block inclusions of loess also occur occasionally in the diamicton mass. Smudges and block inclusions are not abundant features in Des Moines Lobe diamictons, but they are well-preserved in the Acorn Valley Section. Smudges are indicative of active subglacial conditions, and Krüger (1979) associates them with lodgement till deposition.

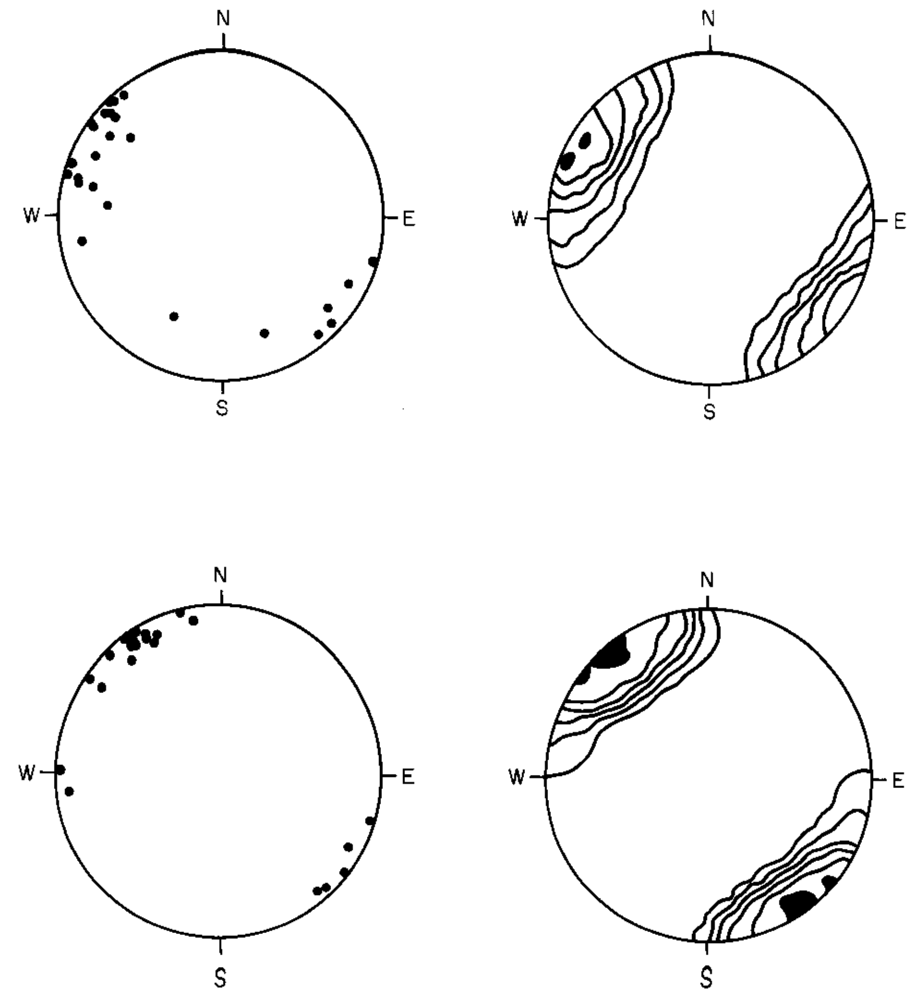
Depositional Environments. Diamicton deposits at Acorn Valley are interpreted to be 'basal tills,' in the sense of Dreimanis (1976), for a number of reasons. Firstly, the sub-horizontal nature of the discontinuous, interbedded sand and gravel lenses suggests deposition on a stable, sub-glacial substrate. Secondly, smudges and shear-truncated channel fills suggest active movement at the glacier sole. Thirdly, pebble fabrics (Fig. 6-3) in the diamicton show consistent, strongly-oriented fabrics typical of basal tills deposited in modern glacial environments (Boulton, 1971; Krüger, 1979; Lawson, 1979, among many others). Fabric 1 was taken just above a smudge of Pennsylvanian shale; it was taken between the 6 and 7 meter distance marks and just above the 7 meter height mark on Fig. 6-1. Fabric 2 was taken near the base of the Des Moines Lobe deposits, beneath one of the shear-truncated channel fills, at the 3 meter distance mark and 3 1/2 meter height mark on Fig. 6-1. Both of these fabrics are among the strongest-oriented fabrics measured by the authors for basal tills on the Des Moines Lobe.

Though the Des Moines Lobe diamictons at Acorn Valley can be interpreted as basal tills, more specific interpretation as lodgement till or melt-out till remains problematic. The shear-related structures (smudges, truncated channel fills) make a lodgement origin a real possibility here, but the shear-related structures are not necessarily related to depositional processes. The sand and gravel lenses could either be deposits in subglacial channels of an actively moving temperate ice sheet (related to lodgement) or drainage channels at the base of or within stagnant debris-rich basal ice (related to melt-out). Modern analogues for either of these two possibilities have not been documented, so comparison is not possible at this time. Interpretation of specific depositional processes remains problematic.

77 ACORN VALLEY SECTION
PEBBLE FABRICS - BASAL TILL

Contour Interval = 2 σ

n=25



Site 1

	Az.	Dip	Sig.
S_1	302°	5°	0.84
S_2	209°	31°	0.13
S_3	40°	59°	0.03

Site 2

	Az.	Dip	Sig.
S_1	320°	3°	0.89
S_2	51°	5°	0.10
S_3	195°	84°	0.01

Figure 6-3. Fabric data for sites 1 and 2 in late Wisconsinan-age Des Moines Lobe diamicton at the Acorn Valley Section. Twenty-five prolate-shaped pebbles were measured for each. On the left data are plotted on lower hemisphere, Schmidt equal-area projections. On the right contoured equal area-projections (contoured according to the method of Kamb, 1959) are shown; contour interval = 2σ. Statistical orientation data calculated by the eigenvector method (Mark, 1973) are also shown.

Secondary Properties. Post-depositional alteration of the Des Moines Lobe deposits consists of normal pedogenic (soil) and weathering-related changes with depth. Leaching and soil formation have affected the upper 1 to 1.5 m (3 to 5 ft). The modern soil was not described or sampled here because of the inaccessibility of the upper part of the section and the extensive tree roots that occur in the upper meter of the exposure. With depth, systematic weathering zone changes (Hallberg et al., 1978) occur from mottled, oxidized, unleached (MOU) to reduced and mottled reduced, jointed, and unleached (RJU and MRJU) (Fig. 6-2). The joints in the Des Moines Lobe diamicton are subvertical and extend down into the underlying Wisconsinan-age loess. Some secondary oxidation and carbonate coatings occur along the joints.

Wisconsinan-age Loess and Basal Loess Sediment

Wisconsinan-age loess is exposed beneath the Des Moines Lobe glacial deposits across the entire Acorn Valley exposure (Fig. 6-1). The upper contact with glacial deposits is an erosional unconformity while the lower contact with older hillslope deposits is another unconformity marked by an erosion surface and a paleosol subsequently developed across the paleohillslope. The loess exposed at Acorn Valley is stratigraphically equivalent to that described in the emergency spillway exposures at Saylorville Dam. The loess has a silt loam texture with low sand content (Fig. 6-2). It is calcareous and contains occasional mollusc shells. Weathering zone relationships are very complex in the loess and range from oxidized to deoxidized. Oxidation along subvertical joints extending from the overlying Des Moines Lobe diamicton adds to the complexity of the weathering zones in the loess.

Relatively uniform, low sand content loess grades downward into sandier, stratified basal loess sediments (BLS) which are are quite variable across the section. On the northern end of the exposure organic zones are stratified within the BLS. Down the paleoslope the lower part of the BLS contains abundant, thin, discontinuous lenses of fine to medium sand. Many of these appear to be filling small rills and depressions in the underlying surface. Between about the 7 and 24 meter distance marks (Fig. 6-1), the BLS rests on a truncated soil surface. The A and upper portions of the E horizon of the underlying Late Sangamon Paleosol were erosionally truncated prior to and/or during accumulation of the BLS in this portion of the paleohillslope. Still farther down the hillslope (between the 0-7 m distance marks) the A horizon of the Late Sangamon Paleosol (LSP) is buried beneath BLS.

The erosion surface developed across the LSP on this buried hillslope is equivalent to the Wisconsinan-age 'Iowan Erosion Surface' (IES) of northeastern Iowa (Ruhe et al., 1968; Hallberg et al., 1978). The IES has been documented throughout Iowa (Esling, 1983; Hallberg et al., 1984; Hallberg et al., 1980; Bettis et al., 1984). The 'Iowan Erosion Surface' is actually a complex of erosion surfaces (i.e., multiple erosion surfaces) cut during the Wisconsinan (Fenton, 1966). The major erosional episode occurred between about 20,000 and 17,000 years ago although the initial IES development probably began much earlier (Hallberg et al., 1980; Ruhe et al., 1968). Erosion of the LSP surface at the base of the BLS at the Acorn Valley Section occurred by slopewash and solifluction. Evidence for solifluction is present in the form of discontinuous pods of sediment bounded on their downslope side by sandy zones. These are evident on the northern end of the exposure where the organic streaks in the BLS are common, and the upper surface of the LSP is deformed.

Late Sangamon Paleosol and Pedisediment

The most prominent feature at the Acorn Valley Section is the Late Sangamon Paleosol (LSP). This soil is developed into hillslope deposits (pedisediment) and underlying, truncated Pre-Illinoian age till of the Wolf Creek Formation. A prominent stone line rests on the surface separating the Pre-Illinoian age till from the overlying pedisediment. The stone line is a lag deposit formed during slope erosion which truncated the till. As erosion proceeded up the paleohillslope, the stoneline on lower portions of the slope was buried by fine-grained material being transported down the hillslope (Canfield et al., 1984). The pedisediment thickens and becomes finer textured downslope. Although the entire slope profile is not exposed here, the thickness of the pedisediment and drainage characteristics of the paleosol indicate that this was a footslope position on the paleohillslope.

The age of the 'Late Sangamon' pedisediment here can only be roughly estimated as pre-late Wisconsinan and younger than the Pre-Illinoian glacial till below the stone line. Since it is buried by loess and BLS it must be older than these deposits. The pedisediment has been referred to as 'Late Sangamon' because the LSP is developed into it. Work elsewhere has suggested that there might be multiple 'Late Sangamon' pediments (Hallberg et al., 1984). Some of these pediments and the pedisediment burying them may be as young as Wisconsinan (early and/or middle) in age, depending on whose classification you are referring to.

In central Iowa the morphologically well-expressed pre-Wisconsinan paleosols developed on the highest 'stable' upland position is the Yarmouth-Sangamon Paleosol (YSP) (Ruhe, 1969). The paleosol at the Acorn Valley Section developed after a period of erosion truncated Pre-Illinoian age deposits and any YSP developed in them. Since we cannot stratigraphically distinguish Sangamon from Yarmouth-Sangamon soils in this part of the Midwest,* technically this paleosol should be referred to as a post-Yarmouth-Sangamon, pre-late Wisconsinan paleosol.

Several features characteristic of pre-Wisconsinan paleosols developed in pedisediment are present in this exposure. Note the discontinuity in grade and size of soil structure from the portion of the LSP developed in pedisediment to those portions developed in the stone line and underlying Pre-Illinoian tills (Appendix 6-1). This discontinuity can be interpreted in two ways: 1) the change in porosity and density from the pedisediment to the underlying material may have promoted accumulation of clay and development of stronger and finer soil structure in the stone line and till; or 2) this soil is polygenetic, the portion below the stone line being an older, partially-truncated soil into which the overlying soil in the pedisediment has further developed. There is not enough information available at this time to determine which of these alternate explanations is most likely.

*Pedostratigraphic units are defined on the basis of their stratigraphic position, not on their relative degree of development (North America Commission on Stratigraphic Nomenclature, 1983).

The pervasive iron staining, abundant accumulation of secondary oxides and cutans (clay coatings), and the moderate to strong (soil) structural development present in the LSP here are usually associated with moderately well to well-drained pre-Wisconsinan buried soils in the Midcontinent (Follmer, 1983; Canfield et al., 1984). A prominent clay bulge in the B horizon (Figs. 6-2, 6-4, and 6-5) here is a result of clay translocation and/or in-place formation of clay minerals. Clay mineralogy of the soil profile indicates significant weathering of the original materials (see paper by Hallberg, this volume).

At profile 3, located farthest down the paleoslope, the A horizon of the LSP is preserved (Appendix 6-1, profile 3). Farther upslope, erosion prior to accumulation of the BLS truncated upper portions of the LSP. The uppermost preserved soil horizon of the LSP at profiles 1 and 2 is an EB horizon (Appendix 6-1, profiles 1 and 2). This is a transition horizon from a former E horizon (now missing because of erosion) to the underlying Bt horizon (Guthrie and Witty, 1982; Bettis, 1984). The E horizon is a zone from which clay and iron compounds have been moved to lower portions of the solum. The presence of silans (silt coatings) and/or platy structure are characteristic of E horizons.

A Bt horizon is present across the entire LSP exposure. This is the portion of the soil profile where clay, iron and other compounds leached from the overlying E horizon have accumulated. The presence of cutans (secondary accumulations of clay along ped faces) and abundant iron staining and coatings are characteristic of Bt horizons.

In the lower part of the solum at profile 1 significant accumulation of oxides (ferro-manganese minerals) has occurred (Appendix 6-1, profile 1). This phenomena is often associated with Late Sangamon Paleosols in Iowa.

Hard, secondary accumulations (concretions) of carbonate minerals (calcite) are present below the solum at profile 1. These are carbonates leached from the original Pre-Illinoian till matrix. Their presence is indicated in the weathering zone terminology by the '2' at the end of the weathering zone designator (Appendix 6-1, profile 1).

Pre-Illinoian Age Glacial Deposits

Pre-Illinoian age glacial deposits are poorly exposed at the Acorn Valley Section. Less than 2 m of the deposits are exposed along the base of the weathering zone section (Fig. 6-1).

The upper surface of the deposits has been truncated by natural subaerial hillslope processes during development of the 'Late Sangamon' erosion surface (Ruhe et al., 1967; Ruhe, 1969). This truncation is marked by an erosion surface consisting of a 'stone line' (Ruhe, 1959), a concentrate of coarser pebbles and cobbles which have been left as a lag deposit as the finer-grained till matrix was eroded away by natural hillslope processes. This stone line and associated pedisediment were discussed previously.

Primary sedimentologic properties of the upper part of the Pre-Illinoian age diamicton deposits have been almost wholly obscured or obliterated by secondary, pedogenic (soil) processes during development of the 'Late Sangamon' Paleosol (LSP). These secondary properties, discussed elsewhere in the guidebook, include oxidation, leaching, development of strong (secondary) soil structure, deposition of secondary clay, iron and manganese oxide coatings, etc.

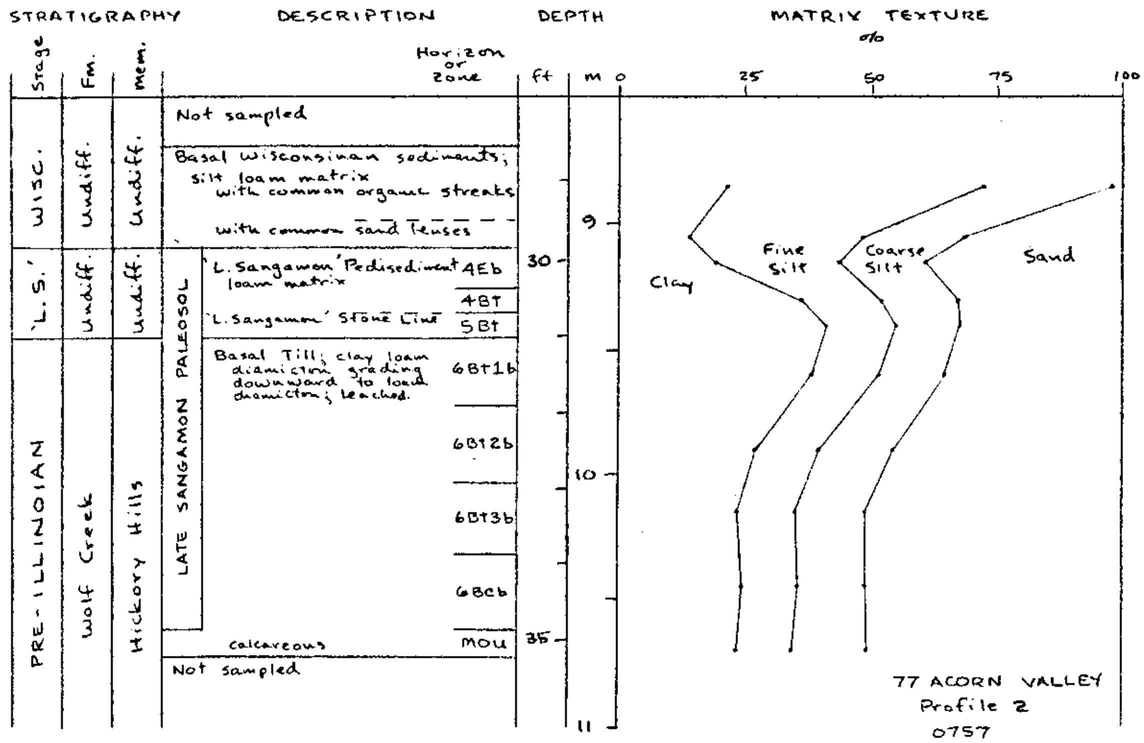


Figure 6-4. Stratigraphy and particle-size of profile 2, Acorn Valley Section.

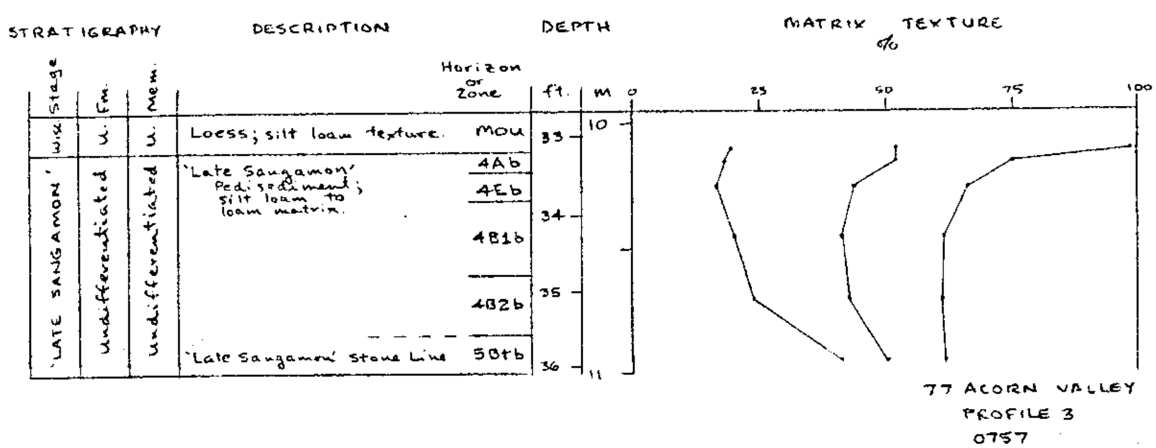


Figure 6-5. Stratigraphy and particle-size of profile 3, Acorn Valley Section. Only the 'Late Sangamon' pedisediment and stone line material was exposed and sampled.

Along the right (northern) edge of the outcrop up to a meter of Pre-Illinoian age diamicton deposits are exposed beneath the solum of the LSP (Fig. 6-1). These deposits are also weathered (Appendix 6-1, description for Section 1). They are mottled oxidized; jointed, with extensive secondary iron oxide coatings along the joints; leached, but with large secondary carbonate concretions in the lower part of the exposure; and with common to abundant secondary iron oxide and manganese oxide coatings and concretions.

Though secondary, weathering-related properties obscure the primary sedimentologic properties of the deposits, the Pre-Illinoian age deposits appear to be dominated by massive, uniform, matrix-dominated diamictons. Detailed sedimentologic studies remain to be done, but the massive properties of the deposits are similar to those of Pre-Illinoian age diamictons interpreted to be basal tills elsewhere in the State. Matrix textures of the Pre-Illinoian diamicton below the LSP are uniform, and identical to textures reported by Hallberg (1980) and Hallberg et al. (1980) for the youngest Pre-Illinoian age till member in eastern Iowa, the Hickory Hills Till Member of the Wolf Creek Formation.

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77AV1
Profile 1 22.1 m
Top of stone line is datum

Depth (cm)	Weathering Zone (Soil Horizon)	Description
		BASAL LOESS SEDIMENT
+50-+34	MOU (3C)	dark grayish brown, brown and pale brown (10YR 4/2, 5/3 and 6/3) stratified silt loam, massive, friable, weak to strong effervescence, abrupt wavy boundary, abundant fine yellowish brown (10YR 5/8) mottles, abundant fine pipestems, occasional soft medium to fine carbonate concretions, occasional charcoal flecks.
		LATE SANGAMON PALEOSOL DEVELOPED IN PEDISEDIMENT
+34-+12	(4EB1b)	strong brown (7.5YR 4/6) loam, moderate medium breaking to weak fine subangular blocky, friable, noneffervescent, clear smooth boundary, abundant fine strong brown (7.5YR 5/6) mottles.
+12-0	(4EB2b)	strong brown (7.5YR 4/6) loam, moderate medium platy breaking to moderate fine subangular blocky, friable, noneffervescent, abrupt irregular boundary, few discontinuous brown (10YR 5/3) silans, abundant fine strong brown (7.5YR 5/8) mottles.
		STONE LINE
0-19	(5Btb)	dark yellowish brown (10YR 4/6) loam matrix-supported cobbles and pebbles, moderate medium angular blocky (matrix), friable, noneffervescent, abrupt irregular boundary, iron staining on pebbles and cobbles, few thin discontinuous brown (7.5YR 4/4) cutans, abundant medium and fine yellowish red (5YR 4/6) mottles.
		PRE-ILLINOIAN TILL (WOLF CREEK FM., HICKORY HILLS MBR.)
19-31	(6Bt1b)	dark yellowish brown (10YR 4/6) clay loam, with common pebbles, moderate to strong fine angular blocky, friable, noneffervescent, gradual smooth boundary, thin almost continuous brown (7.5YR 4/4) cutans, few fine oxides.

77AV1 - Profile 1
CONTINUED

Depth (cm)	Weathering Zone (Soil Horizon)	Description
31-45	(6Bt2b)	strong brown (7.5YR 4/6) clay loam with pebbles as above, strong fine angular blocky, friable, noneffervescent, clear smooth boundary, thick continuous brown (7.5YR 4/4) cutans, oxides as above, common medium grayish brown (10YR 5/2) mottles.
45-64	(6Bt3b)	strong brown (7.5YR 4/6-5/6) clay loam to loam, strong fine angular blocky, friable, non-effervescent, clear smooth boundary, thick continuous brown (7.5YR 4/4) cutans, oxides and mottles as above, occasional slickensides, faint iron stained joints, occasional fine pebbles.
64-81	(6Bt4b)	strong brown (7.5YR 4/6) loam, strong medium to fine angular blocky, friable, noneffervescent, clear smooth boundary, thick continuous brown (7.5YR 4/4) cutans, common thin discontinuous oxides on cutans, iron stained joints common and prominent, occasional fine pebbles.
81-99	(6BCb)	light brownish gray to light yellowish brown (10YR 6/2-6/4) loam, moderate coarse angular blocky, friable, noneffervescent, abrupt smooth boundary, joints as above, occasional patches of brown (7.5RY 4/4) thin cutans in joints, abundant fine oxides, occasional medium to fine pebbles.
99-109	(6CBb)	as above except abundant oxides on peds.
109-179	MJOL (6C1)	brown to grayish brown (10YR 5/3-5/2) loam, massive but breaks into coarse angular blocks, friable, noneffervescent, strong brown (7.5YR 5/6-4/6) accumulations on faces of coarse blocks, prominent joints with 3-5 cm thick strong brown (7.5YR/4/6-5/6) oxidation rinds, occasional fine pebbles.
179-base (209)	MJOL2 (6C2)	brown to grayish brown (10YR 5/3-5/2) loam, massive but breaks to coarse angular blocks, friable, staining along joints as above, moderate to strong effervescence, common medium hard secondary carbonate accumulations, common medium to fine strong brown (7.5RY 5/6) mottles, common pebbles and occasional cobbles, granitics are soft and crumbly.

77AV1
Profile 2 12.5 m
Top of stone line is datum

Depth (cm)	Weathering Zone (Soil Horizon)	Description
		BASAL LOESS SEDIMENT
+65-+37	MOU2 (3C1)	brown (10YR 5/3) silt loam, massive, friable, moderate effervescence, abrupt wavy boundary, common organic streaks, common fine yellowish brown (10YR 5/6) mottles, few fine soft carbonate concretions.
+37-+26	MOU (3C2)	brown (10YR 5/3) silt loam with common 1-3 cm thick lenses of fine sand, massive, friable, moderate effervescence, abrupt wavy boundary, mottles as above.
		LATE SANGAMON PALEOSOL DEVELOPED IN PEDISEDIMENT
+26-+10	(4EBb)	strong brown (7.5YR 5/6) loam, moderate medium platy, friable, noneffervescent, clear smooth boundary, common fine brown (7.5YR 5/2) mottles, common fine iron concretions.
+10-0	(4Btb)	strong brown (7.5YR 5/6) clay loam, moderate fine angular blocky, friable, noneffervescent, abrupt irregular boundary, few thin discontinuous strong brown (7.5YR 4/6) mottles, few fine oxides.
		STONE LINE
0-10	(5Btb)	strong brown (7.5YR 4/6) clay with abundant pebbles and cobbles (stone line), strong fine angular blocky, friable, noneffervescent, clear irregular boundary, thick continuous brown (7.5YR 4/4) cutans, common fine oxides, few medium yellowish red (5YR 4/6) mottles.
		PRE-ILLINOIAN TILL (WOLF CREEK FM., HICKORY HILLS MBR.)
10-37	(6Bt1b)	strong brown (7.5YR 5/6) clay loam, strong fine angular blocky, friable, noneffervescent, clear smooth boundary, common thin discontinuous brown (7.5YR 4/4) cutans, few fine oxides, abundant medium brown (7.5YR 5/2) mottles.
37-68	(6Bt2b)	strong brown (7.5YR 5/6) sandy clay loam, moderate medium to fine angular blocky, friable, noneffervescent, gradual smooth boundary, cutans and mottles as above.

77AV1 - Profile 2
CONTINUED

Depth (cm)	Weathering Zone (Soil Horizon)	Description
68-97	(6Bt3b)	grayish brown (10YR 5/2) sandy clay loam, moderate medium subangular blocky, friable, noneffervescent, gradual smooth boundary, thin continuous strong brown (7.5YR 4/6) cutans, few fine oxides, few fine pebbles.
97-127	(6RCb)	grayish brown to brown (10YR 5/2-5/3) loam, weak fine columnar, friable, clear smooth boundary, few thin brown (7.5RY 4/4) iron accumulations on ped surface, thick brown (7.5YR 4/4) oxidation rinds along joints, common medium strong brown (7.5YR 5/6) mottles and streaks.
127-base (137)	MJOL (6C)	as above but with weak effervescence.

77AV1
Profile 3   5.7 m
Datum is top of stone line

Depth (cm)	Weathering Zone (Soil Horizon)	Description
		WISCONSINAN LOESS
+74	MOU-MDU (2C)	grayish brown to light olive brown (2.5Y 5/2-5/4) silt loam, massive, friable, weak effervescence, abrupt smooth boundary, few fine yellowish brown (10YR 5/6) mottles.
		LATE SANGAMON PALEOSOL DEVELOPED IN PEDISEDIMENT
+74-+66	4Ab	brown to yellowish brown (10YR 5/3-5/4) silt loam, weak fine platy, very friable, non-effervescent, clear smooth boundary, occasional charcoal flecks, common fine yellowish brown (10YR 5/6) mottles.
+66-+54	4Eb	dark yellowish brown (10YR 4/6) loam, weak medium to fine subangular blocky, friable, non-effervescent, clear smooth boundary, occasional charcoal flecks, common light gray (10YR 7/2) silans.
+54-+24	4B1b	dark yellowish brown to strong brown (10YR 4/6-7.5YR 4/6) loam, moderate medium subangular blocky breaking to moderate fine angular blocky, friable, noneffervescent, gradual smooth boundary, few charcoal flecks, abundant silans, few fine oxides, abundant fine strong brown (7.5YR 5/6) mottles.
+24-0	4B2b	strong brown (7.5YR 4/6-5/6) loam, moderate medium to fine subangular blocky, friable, noneffervescent, abrupt irregular boundary, silans and oxides as above, abundant fine grayish brown (10YR 5/2) mottles.
		STONE LINE
0-14 (base of exposure)	5Bt	strong brown (7.5YR 4/6) clay loam with abundant medium pebbles (Stone line), strong fine angular blocky, friable, abundant thin discontinuous brown (7.5YR 4/4) cutans, abundant fine grayish brown (10YR 5/2) mottles.

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