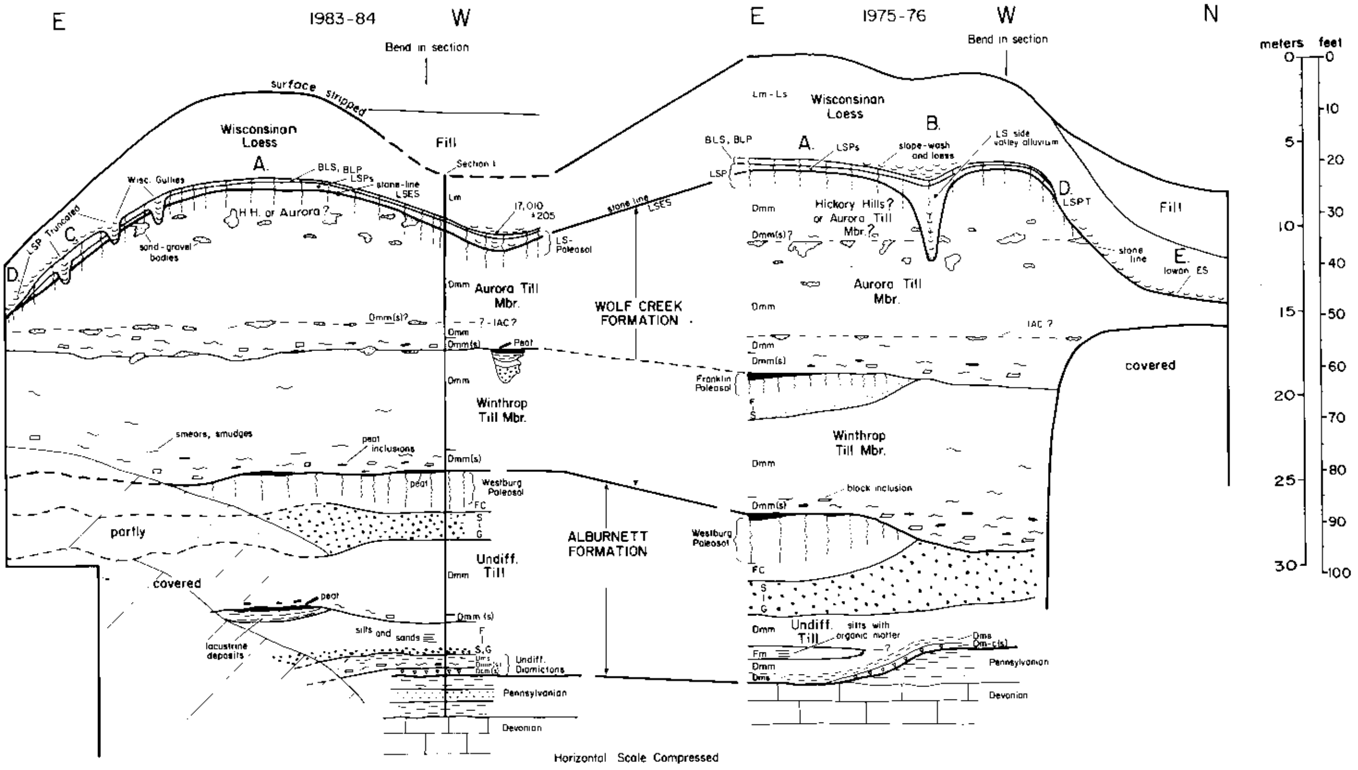
UNDERBURDEN — OVERBURDEN

An Examination of Paleozoic and Quaternary Strata at the Conklin Quarry Near Iowa City



Edited by Bill J. Bunker and George R. Hallberg

Quaternary Stratigraphy:
George R. Hallberg, Timmothy J. Kemmis, Nyle C. Wollenhaupt,
Steven P. Esling, E. Arthur Bettis III, Thomas J. Bicki

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Brian F. Glenister, Philip H. Heckel,
Brian J. Witzke, Bill J. Bunker

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Mineralization:
Paul L. Garvin

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UNDERBURDEN-OVERBURDEN: An examination of Paleozoic and Quaternary strata at the Conklin Quarry near Iowa City

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THE UNDERBURDEN: THE DEVONIAN STRATIGRAPHIC SEQUENCE AT CONKLIN QUARRY

by Brian J. Witzke and Bill J. Bunker

The upper portion of the Wapsipinicon Formation and all three members of the Cedar Valley Formation are exposed at the River Products' Conklin Quarry (secs. 32 and 33, T.80N., R.6W.). The main focus of this section is purely descriptive; interpretations of the depositional environments are discussed by Glenister and Heckel elsewhere in this guidebook. Lithologic and paleontologic symbols used on the accompanying stratigraphic diagrams are shown in figure 1. We will examine this Middle Devonian limestone sequence in the main pit of the active quarry area.

Please exercise caution when in the quarry. Wear hard hats at all times. Stay clear of quarry faces exhibiting broken or unstable surfaces.

Wapsipinicon Formation

The Wapsipinicon Formation in the Iowa City area unconformably overlies Silurian dolomite formations and includes three members, in ascending order, Kenwood, Spring Grove, and Davenport. We will examine the upper portion of the Davenport Member in the main pit (fig. 2), although laminated and petroliferous dolomites of the Spring Grove Member are noted at the base of the old quarry area. The Davenport Member is a limestone unit that is, in part, prominently brecciated. Massive beds of weakly laminated "sublithographic" limestone are replaced laterally by brecciated beds containing limestone clasts of similar lithology; the angular clasts range from less than 1 cm up to 1 m in diameter. The limestone matrix of the breccias is locally sandy to very sandy, and irregular argillaceous swirls and thin beds of slightly argillaceous, irregularly-laminated to swirled limestone occur in the upper protion.

The limestone breccias in the Wapsipinicon originated by solution-collapse processes; as interbedded evaporite layers (gpysum-anhydrite) dissolved, the carbonate beds fractured and collapsed. Wapsipinicon evaporites are still preserved in the subsurface of southern Iowa, but are absent to the north, where extensive breccias occur. Solution-collapse was, in part, coincident with deposition of overlying Cedar Valley strata, and clasts of fossiliferous Solon limestone are noted locally in the upper Wapsipinicon breccias. Irregular bedding and small-scale faulting, which developed contemporaneous with lower Cedar Valley deposition, is apparent in the Cedar Valley sequence up to the middle portion of the Rapid Member. Locally, small-scale reverse faults terminate vertically in the lower Rapid sequence, and these can be explained reasonably as a consequence of penecontemproaneous collapse of underlying Wapsipinicon strata. The Davenport-Solon contact is an irregular surface which marks an abrupt change in lithology.

KEY

Figure 1. Key to lithologic and paleontologic symbols used on Paleozoic stratigraphic sections in this guidebook.

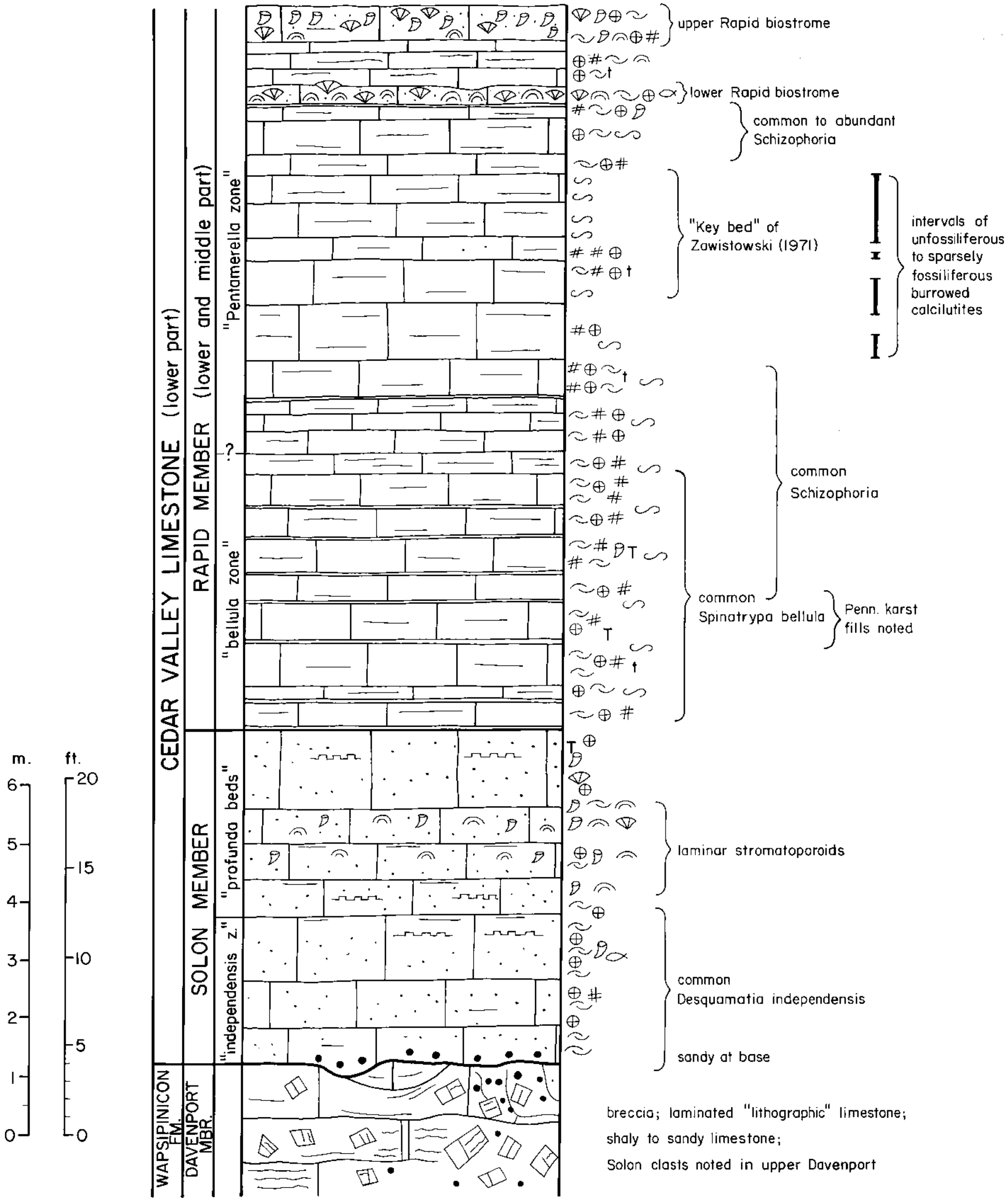

Figure 2. Lower portion of Devonian stratigraphic sequence in main pit, Conklin Quarry.

Solon Member

The Solon, the lower member of the Cedar Valley Formation, is dominated by fossiliferous skeletal calcarentite (figure 2). The basal portion of the Solon at the Conklin quarry includes thin, discontinuous lenses of sandstone and sandy limestone up to 15 cm (6 in) thick; the medium to coarse sand grains are composed of quartz and chert (Kettenbrink, 1973, p. 22). The Solon calcarenites are slightly argillaceous, and contain an abundance of skeletal debris. Stainbrook (1941) divided the Solon into two units based on faunal content, the lower "*independensis* zone" and the upper "*profunda* beds." The lower zone, which derives its name from the common atrypid brachipod, *Desquamatia independensis*, includes abundant fossils, dominantly brachipods with varying amounts of crinoidal debris. This interval also includes occasional sponges, solitary rugose and other corals, bryozoans, mollusks, trilobites, and fish debris. The brachiopod fauna is diverse, with *Desquamatia, Spinatrypa, Schizophoria, Strophodonta,* and *Gypidula* generally being the most common (Koch, 1978). Other brachiopods of note include additional spiriferids *(Tylothyris, Orthospirifer, Eosyringothyris, Elita, Cyrtina)*, strophomenids *(Schuchertella, Pholidostrophia, Productella,* chonetids*)*, rhynchonellids *(Hypothyridina)*, and terebratulids *(Cranaena)*.

The upper Solon "*profunda* beds" which derive their name from the colonial rugose coral *Hexagonaria profunda*, include biostromal stromatoporoid-coral accumulations at other localities in Johnson County (Mitchell, 1977). at localities north of Johnson County, uppermost Solon strata contain an abundance of terebratulid brachiopods (the "*Rensselandia* beds"). The upper Solon at Conklin Quarry is characterized by calcarenite beds containing an abundance of thin, laminar stromatoporoids (fig. 2) with scattered small solitary rugosans. The uppermost beds contain some favositid and colonial rugose corals. Brachiopod and crinoid debris is a significant component of the "*profunda* zone" calcarenites, with lesser quantities of bryozoan grains. The brachipod fauna of the upper Solon generally resembles that of the lower Solon at the generic level, although *Gypidula* is absent. Large specimens of *Orthospirifer iowensis* are prominent in some beds. Chitinozoans have been recovered from the Solon sequence at this locality (Dunn, 1959).

Several dark-colored hardgrounds or discontinuity surfaces are noted in the Solon sequence at Conklin Quarry (figure 2). Fractures and voids within the Solon limestones are sites of calcite and sulfide mineralization. The best specimens of millerite are found in calcite-lined voids in the Solon. The Solon-Rapid contact at the Conklin Quarry is gradational, and there is a general "lack of clear physical criteria" for defining its position (Kettenbrink, 1973, p. 57). For general purposes, the boundary is drawn at the first prominent shaly calcilutite above the stromatoporoidal and coralline Solon calcarenites. The vertical change from skeletal calcarenite to argillaceous calcilutite defines the approximate position of the Solon-Rapid boundary.

Rapid Member

The Rapid Member, the middle member of the Cedar Valley Formation, is dominated by argillaceous, skeletal calcilutite. Thin shales or shaly limestones commonly separate the calcilutite beds. Insoluble residue content of the Rapid Member (primarily illite) averages about 11% (Kettenbrink, 1973). The argillaceous calcilutites are bioturbated to varying degrees. Chitinozoans have been recovered from the Rapid Member in the Conklin Quarry (Dunn, 1959).

Following Stainbrook (1941), the Rapid Member is divided into three macrofaunal "zones." The "*bellula* zone," named after the characteristic atrypid *Spinatrypa bellula*, encompasses the lower interval of the Rapid Member (figure 2). Brachiopod, crinoid, and bryozoan grains are the dominant skeletal constituents in this interval. The brachiopod fauna is diverse and includes spiriferids *(Spinatrypa, Pseudoatrypa, Orthospirifer, Eosyringothyris, Tylothyris, Elita, Cyrtina, Athyris)*, orthids *(Schizophoria)*, strophomenids *(Strophodonta, Productella*, chonetids), and terebratulids *(Cranaena)*. Disarticulated crinoid debris is common; the largest columnals are probably from *Megistocrinus*. An articulated crinoid specimen collected at Conklin Quarry probably came from these beds (Calhoun, 1983). Cryptostome (especially fenestellids) and trepostome bryozoans are important faunal elements, contrasting with the underlying Solon faunas. The "*bellula* zone" contains scattered corals in some beds; tabulates (pachyporids, *Favosites*) and rugosans are noted. Trilobites and mollusks also occur. The top of the "*bellula* zone" is drawn above the highest occurrence of *Spinatrypa bellula*.

The middle portion of the Rapid Member is included in the "*Pentamerella* zone," named after the characteristic pentamerid brachiopod (Stainbrook, 1941). The lower portion of this interval resembles "*bellula* zone" strata, and contains common brachiopods, cryptostome and trepostome bryozoans, and crinoid debris, with some pachyporid tabulate corals. The brachiopod fauna is dominated by *Schizophoria, Pseudoatrypa, Orthospirifer, Tylothyris*, and *Strophodonta. Pentamerella, Eosyingothyris, Cyrtina*, and *Productella* also occur. Skeletal debris commonly is concentrated into lenses or stringers within the argillaceous calcilutites. The middle portion of the "*Pentamerella* zone" includes intervals of unfossiliferous to sparsely fossiliferous, burrowed argillaceous calcilutites termed the "Key bed" by Zawistowski (1971) (figure 2). Pyritized burrows are conspicuous in this interval. Intervals of skeletal calcilutite with calcarenitic lenses, often containing abundant bryozoans, occur within the lower part of the "Key bed." However, the bulk of the "Key bed" differs from other argillaceous calcilutites of the Rapid Member in the paucity of skeletal grains and sparse faunal content. Zawistowski (1971, p. 38) and Kettenbrink (1973, p. 32) recorded psilophyte plant remains, inarticulate brachiopds, bivalves, branchiopod crustaceans, conularids, and trilobites from "Key bed" strata. An interval of typical Rapid argillaceous skeletal calcilutite occurs above the "Key bed" and below the Rapid biostromes, which contains thin calcarenitic lenses. This interval contains a characteristic Rapid Fauna, including abundant *Schizophoria* and other brachiopod *(Orthospirifer, Cyrtina, Pseudoatrypa, Tylothyris, Strophodonta)*, trepostome and cryptostome bryozoans, and crinoid debris.

Two prominent and widely traceable coralline biostromes occur in the upper portion of the "*Pentamerella* zone" (figure 2). The lower biostrome contains abundant hemispherical and encrusting stromatoporoids and common colonial rugose corals *(Hexagonaria)*; favositid, alveolitid, and solitary rugose corals occur in lesser numbers (Zawistowski, 1971). Many of the coral heads are overturned and encrusted with stromatoporoids. The matrix of the lower biostrome is an argillaceous calcilutite to calcarenite with crinoid debris. The sharp basal contact probably is a discontinuity surface, and commonly includes glauconitic and phosphatic material (fish debris). The lower and upper Rapid biostromes are separated by an interval of argillaceous calcilutite with brachiopods *(Pseudoatrypa, Orthospirifer, Schizophoria)*, bryozoans, coarse crinoid debris, pachyporid tabulate corals, and scattered stromatoporoids. The upper Rapid biostrome is a skeletal framework of solitary and colonial rugose corals, and favositid and alveolitid tabulate corals also occur in the matrix of skeletal calcilutite and calcarenite. Unlike the lower biostrome, the upper biostrome contains only sparse stromatoporoids, and coral heads generally are not overturned (ibid.). Several genera of solitary rugosans (Pitrat, 1962) are especially abundant in the upper biostrome in the Conklin Quarry.

The "*waterlooensis* zone" includes the upper Rapid interval of argillaceous calcilutites above the biostromes (figure 3). It derives its name from the characteristic large atrypid brachiopod, *Desquamatia waterlooensis* (Stainbrook, 1941). The "*waterlooensis* zone" is dominated by argillaceous skeletal calcilutite with calcarenitic lenses, and is glacuconitic to varying degrees. Thin shaly units commonly separate the calcilutite beds. The diverse brachiopod fauna is dominated by *Desquamatia, Orthospirifer, Eosyringothyris, Tylothyris, Cyrtina,* and *Strophodonta*, but many additional taxa are present. Trepostome and cryptostome (especially fenestellids, *Sulcoretopora*) bryozoans are common in some beds. The echinoderm fauna of the "*waterlooensis* zone" is the most diverse known in the Cedar Valley sequence of eastern Iowa, and includes camerate, flexible, and inaduante crinoids, blastoids, and rhombiferan cystoids. Articulated cystoid theca (*Strobilocystites*) and crinoids have been collected from these strata at the Conklin Quarry. Trilobite and fish debris are occasionally found. The upper half of the "*waterlooensis* zone" contains common small pachyporid tabulate corals.

Chert nodules occur near the middle of the "*waterlooensis* zone" in the main pit of the Conklin Quarry (figure 3). Some of the chert nodules are silicified skeletal calcarenites. Dark colored discontinuity surfaces, or hardgrounds, are developed in this interval (figure 3). One in the lower half of the unit is especially prominent and exhibits subvertical burrows up to 12 cm (5 in) long. The top of the Rapid Member is drawn at a sharp burrowed discontinuity surface. This surface marks the boundary separating argillaceous calcilutite below and coralline calcarenite above. Calcarenite-filled burrows penetrate the discontinuity surface. Packstones of *Desquamatia waterlooensis* commonly occur above the uppermost Rapid discontinuity surface at the Conklin Quarry.

Coralville Member

The Conklin Quarry is the type locality for the Coralville Member, the upper member of the Cedar Valley Formation. The Coralville Member is the most lithologically variable and stratigraphically complex unit of the Cedar Valley. The basal portion of the Coralville has been termed the "*Cranaena* zone," after the characteristic terebratulid brachiopod (Stainbrook, 1941). The "*Cranaena* zone" in the Iowa City area is a biostromal skeletal calcarenite with abundant encrusting and hemispherical stromatoporoids, tabulate corals

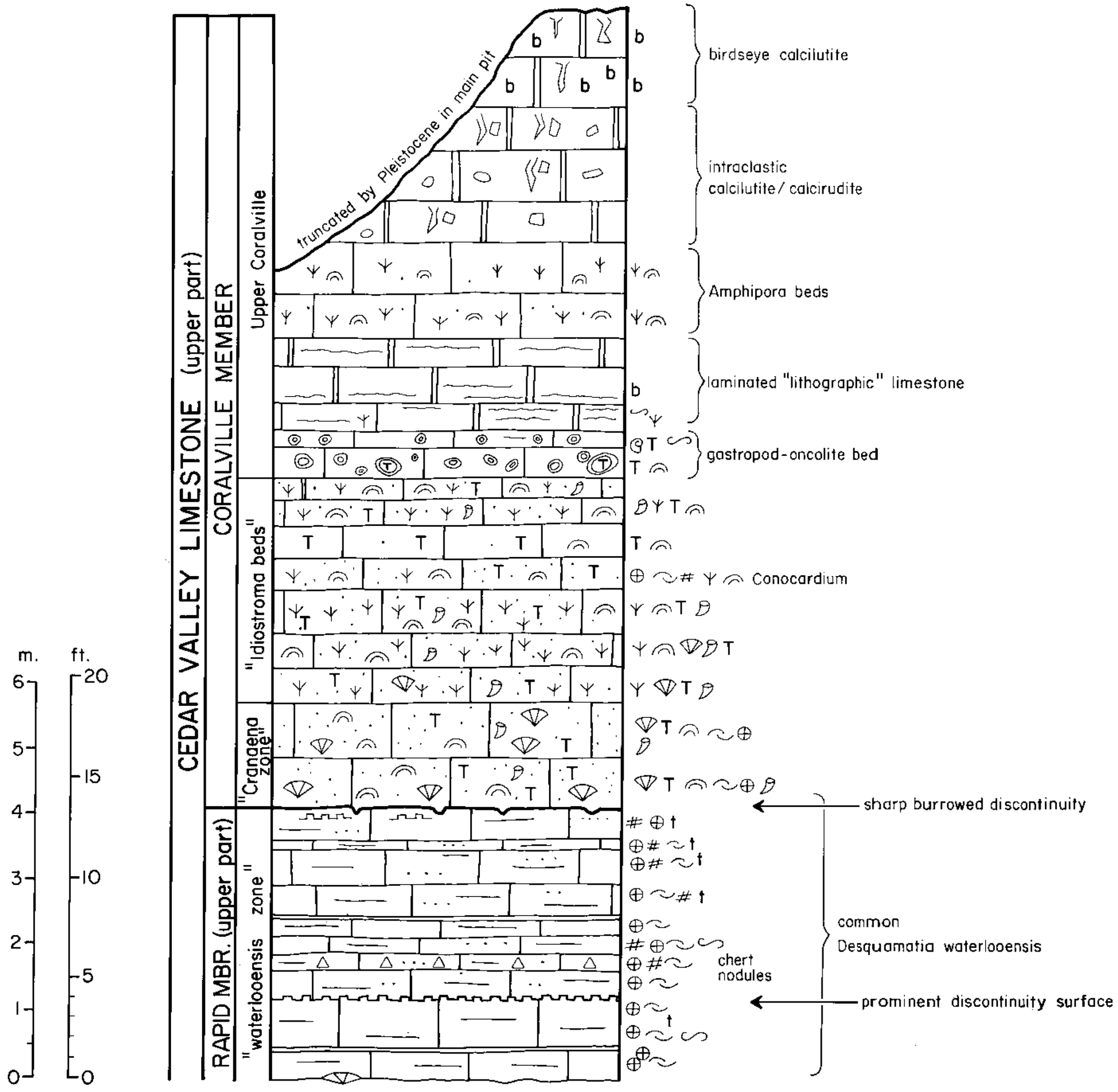

Figure 3. Upper portion of Devonian stratigraphic sequence in main pit, Conklin Quarry.

(favositids), and colonial rugose corals (*Hexagonaria*); the corals and stromatoporoids are commonly overturned. Solitary rugosans are also common (Pitrat, 1962). Crinoid debris, trilobites, bryozoans, brachiopods, algae, and foraminifera are noted in the unit (Kettenbrink, 1973; Witzke, 1984).

A biostromal calcarenitic interval containing scattered to abundant branching stromatoporoids (*Idiostroma*) overlies the "*Cranaena* zone" and is termed the "*Idiostroma* beds" (figure 3). Kettenbrink and Heckel (1975) labelled a thinner interval of packed *Idiostroma* at the Conklin Quarry the "*Idiostroma* bed," but the term is used here to include the entire interval containing *Idiostroma*. In addition to abundant branching stromatoporoids, hemispherical stromatoporoids, massive to ramose favositid corals, and solitary and colonial (*Hexagonaria*) rugose corals are also common. Brachiopods, crinoid debris, rostroconchs (*Conocardium*), algae, and foraminifera also occur in the "*Idiostroma* beds" (Kettenbrink, 1973, Witzke, 1984).

The upper Coralville at the Conklin Quarry was divided by Kettenbrink (1973, p. 49) into five lithologic units which include, in ascending order: 1) "gastropod-oncolite calcilutite," 2) "laminated 'lithographic' limestone," 3) "*Amphipora*-rich pelleted calcilutite," 4) "intraclastic calcilutite to calcirudite," and 5) "'birdseye' calcilutite" (figure 3). A slightly different upper Coralville sequence occurs in the University of Iowa campus area in Iowa City (Witzke, 1984). The Upper Coralville sequence is truncated beneath Pleistocene and Pennsylvanian strata in the main pit area of the Conklin Quarry, and uppermost Coralville strata are not easily accessible in this area of the quarry. The interesting "gastropod-oncolite bed" is characterized by large algal-coated bioclasts. The overlying laminated calcilutites are largely devoid of fossils. The "*Amphipora* beds" are similar to the "*Idostroma* beds" in containing an abundance of branching stromatoporoids (*Amphipora*), but the fauna is of lower diversity (including algae, foraminifera, and ostracodes). Strata above the "*Amphipora* beds" were deposited in intertidal and supratidal settings (Kettenbrink and Heckel, 1975). The "birdseye beds" are characterized by an abundance of small spar-filled bubble-like voids that give the unit its name. Mudcracked and fractured calcilutites and vadose pisoliths occur in the upper beds. The upper Coralville sequence records deposition in increasingly restricted marine, nearshore, and supratidal environments that developed during an episode of offlap of the Cedar Valley sea from the area.

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THE DEVONIAN CEDAR VALLEY LIMESTONE AT CONKLIN QUARRY - ENVIRONMENTS OF DEPOSITION

by Brian F. Glenister and Philip H. Heckel

Merrill A. Stainbrook devoted most of his professional life to biostratigraphic documentation of the Cedar Valley Limestone (e.g., 1935, 1941, 1944). Subsequent detailed sedimentologic studies of part or all of the formation and of the associated State Quarry Limestone have been pursued by Zawistowski (1971), Kettenbrink (1973), Watson (1974) and Mitchell (1977) as part of their graduate studies at the University of Iowa. Herein we summarize conclusions on Devonian environments of deposition at Conklin Quarry reached during these collaborative studies and our independent investigations.

Analysis of trends in both lithofacies and biofacies, supplemented by consideration of bedding relationships and sedimentary structures, permit confident interpretation of the Solon and Coralville members. However, alternative interpretations persist for the Rapid Member, the middle unit of the Cedar Valley Limestone.

Solon Member

The Solon comprises 6 m (20 ft) of brown skeletal wackestone, packstone, and boundstone. Contact with the underlying Davenport Member of the Wapsipinicon Formation occurs at the top of a 2 m (6.5 ft) exposure of breccia composed of large angular clasts of lithographic Davenport limestone, but including angular blocks of Solon and skeletal and chert-quartz sand matrix. The base of the member coincides with the upper limit of Davenport breccia clasts, and is commonly marked by discontinuous lenses and pods of distinctive black or white chert grains and quartz sand. Similar grains are disseminated by stratigraphic leak throughout the exposed Davenport section. The upper one-half of the member comprises wackestones and packstones, commonly bound by thin laminar stromatoporoids into a sparse biostrome. Contact with the overlying wackestone of the Rapid Member is gradational in both lithofacies and biofacies.

Bedding is disrupted chaotically throughout the Solon, especially near the base. This feature alone would serve to distinquish the Solon from other members of the Cedar Valley.

Faunal diversity is greater in the Solon than elsewhere in the Cedar Valley, with abundant and characteristic representation of the biota extending to the base. Probable blue-green algae occur rarely throughout the member. Sponges, including distinctive thinly-laminar but laterally extensive stromatoporoids are a conspicuous element, especially in the biostrome. Corals are represented by favositid, auloporid and alveolitid tabulates, and by both solitary and colonial rugosans. Fenestrate (cryptostome) and stony (trepostome) bryozoans are present throughout, but are not as common as in the Rapid Member. Brachiopods are the dominant faunal element: they exhibit high diversity and large size throughout, the spiriferids achieving hinge widths of 10 cm. Bivalves, gastropods, and breviconic and coiled nautiloid cephalopods are sporadically abundant: trilobites and several vertebrate groups (ptyctodont and arthrodire placoderms, and crossopterygians) occur also. Crinoid ossicles are present throughout the Solon, but articulated specimens are rare.

Brecciation of the Davenport and lower Solon is attributable to evaporite collapse, perhaps initiated during possible pre-Solon emergence but continuing after lithification of the lower Solon. Disruption of bedding throughout the Solon and into the lower Rapid reflects duration of collapse. The chert and quartz sand that marks the basal Solon and leaks into the Davenport was probably derived from the Ordovician and Silurian of the Ozark Uplift.

Winnowing of mud was rarely fully effective, but occurred throughout the Solon interval suggesting open circulation. Assuming that the grains have not been transported significantly, the presence of algae and the large size and diversity of the invertebrates confirm open circulation under "normal" marine conditions. The thin tabular growth form of the stromatoporoids in the Solon biostrome is not duplicated elsewhere in the formation. It is interpreted as a response to an unstable substrate that would not support domal growth forms.

In the Lake McBride area, 12 km (7.5 mi) north of Conklin Quarry, growth of invertebrates in the upper Solon was far more luxuriant, resulting in dense boundstones that mound into numerous bioherms with relief of up to 3 m (10 ft). Reason for the location of the individual bioherms has not been demonstrated conclusively. However, it seems probable that biostromal development was initiated on slight topographic highs produced by differential collapse following solution of the evaporites in the underlying Wapsipinicon Formation, and that topographic prominence was perpetuated by mound growth.

Rapid Member

The Rapid comprises 13.5 m (44 ft) of bluish-grey argillaceous skeletal wackestone with numerous thin (less than 10 cm) packstone interbeds that consist primarily of concentrations of the same organisms that occur scattered in the wackestones. The base of the member is taken at the lowest of several recessive thin shales above the Solon biostrome. A deeply burrowed mineralized hardground discontinuity surface separates the wackestones of the upper Rapid from the grainstones and packstones of the lower Coralville Member.

Several marker beds in the upper Rapid maintain clear continuity throughout the quarry. Particularly conspicuous are two biostromes, the lower 0.3 m (1 ft) and the upper 1 m (3 ft) thick, that maintain their identity for at least 60 km (36 mi) along depositional strike throughout Johnson and Cedar counties. A deeply-burrowed hardground 1 m (3 ft) above the top of the upper biostrome closely resembles the surface that forms the top of the member.

Faunas of the Rapid Member are strikingly different from those below and above, although there is gradational change from the upper Solon. Three groups of organisms predominate, except in the biostromes: the brachiopods, fenestrate bryozoans, and crinoids characterize both the main mass of wackestone and the thin packstone interbeds, although several intervals are virtually devoid of body fossils. Brachiopod diversity is lower than in the

Solon; however, some beds are crowded with small specimens (length 1 cm) of a few species. Fenestellid bryozoans are abundant in many horizons, sporadically in association with trepostomes. A much higher degree of articulation differentiates the Rapid crinoids from those of either the Solon or Coralville, and a diverse echinoderm fauna is recognizable. Corals occur throughout the member, but except in the biostromes they comprise virtually only a single species, a delicate branching pachyporid tabulate with erect growth habit. Rare massive rugosans and tabulates occur sporadically in the wackestone interbeds.

Striking community successions are displayed in the biostromes, particularly the upper biostrome. The succession begins with a thin shell-hash similar to the wackestone interbeds that occur throughout the rest of the member. This is followed, in turn, by a thicket of robust solitary rugose corals and the succeeding climax community of massive hemispherical rugosan and tabulate corals and large horn corals. Growth of both biostromes was terminated abruptly by return to the background wackestone sedimentation that characterizes the Rapid. Only in one area, the M.A. Stainbrook Geologic Preserve at Mehaffey Bridge 8 km (5 mi) north of Conklin Quarry, is the upper Rapid biostrome known to mound into a biohermal complex.

Faunas of the Rapid Member are interpreted to represent stress biotas, characterized by smaller size and lower diversity yet with sporadically greater abundance than those of the Solon. Common occurrence of articulated crinoids and high mud content attest to lowered background levels of water agitation. However, periodically effective winnowing of mud is indicated by the shell concentrations of the packstone interbeds. Erect growth habit of the ubiquitous pachyporid tabulates represents a response to stress of muddy substrates, and is duplicated by red algae, corals, and other organisms living today. Winnowing of mud was sufficiently effective at several horizons to permit colonization of shelly substrates by scattered massive corals. However, only in the case of the biostromes of the upper Rapid was winnowing complete enough to allow colonizaton by robust rugosans and initiation of the community succession that climaxed with massive tabulate and rugose corals. Greater turbulence in the biostromes is indicated by common overturning of even the largest colonies, some of one-half meter diameter.

Two models have been developed to explain known facies relationships in the Rapid Member. The shallow-water hypothesis envisages water depths that were generally too small to sustain effective wave motion and winnowing of the mud. Sporadic occurrence of packstone interbeds and the two biostrome would then have resulted from increase in water depth by the few decimeters necessary to sustain wave and current action that could effect winnowing. The alternative model involves greater water depths below the reach of normal wave action. Horizons with relatively little mud would then reflect winnowing by storm waves.

Coralville Member

The uppermost member of the Cedar Valley Limestone comprises 10 m (33 ft) of brown limestone that exhibits reduction in grain size from skeletal grainstone at the base to calcitic mudstone virtually free of grains near the top. Birdseye structures and large polygonal desiccation features characterize the uppermost bed.

Massive hemispherical rugosan and tabulate corals one-half meter in diamater and comparably-sized stromatoporoids, all comonly overturned, are associated with large solitary corals and abundant brachiopods and rostroconchs in the wackestones of the lowermost Coralville. Change in growth form and reduction in size of both the corals and the stromatoporoids, as well descrease in overall biotic diversity, accompanies the upward decrease in carbonate grain size. A dense thicket of robust erect branching stromatoporoids comprising the *Idiostroma* biostrome succeeds the massive head corals of the basal Coralville. Tabulate corals persist into the middle Coralville, but here they assume irregular domal and then digitate form. The highest abundant megafossils comprise the delicate erect stromatoporoids of the upper Coralville *Amphipora* biostrome. Brachiopods and echinoderms are conspicuously absent from the upper Coralville, although rare gastropods persist to the top of the unit and ostracodes, algae and foraminifers occur throughout.

Both biofacies and lithofacies trends attest to progressive upward restriction and terminal shoaling in the Coralville Member. Water depth was initially sufficient to support wave and current motion that winnowed essentially all mud. Accumulation of sediment resulted in progressive shallowing accompanied by less effective winnowing of mud and eventual "fillup" of the water column. Biofacies response was a decrease in size and diversity as shallowness reduced circulation and imposed progressively greater stress on all but the most ecologically tolerant organisms.

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CONODONT ZONES AND CORRELATION OF THE CEDAR VALLEY-STATE QUARRY INTERVAL OF EASTERN IOWA

by Bill J. Bunker and Gilbert Klapper

Four (5?) conodont zones are recognized in the Cedar Valley-State Quarry interval of eastern Iowa and western Illinois. They are briefly discussed in ascending order, and their inferred correlation with the standard European and western North American zonation is shown in figure 1.

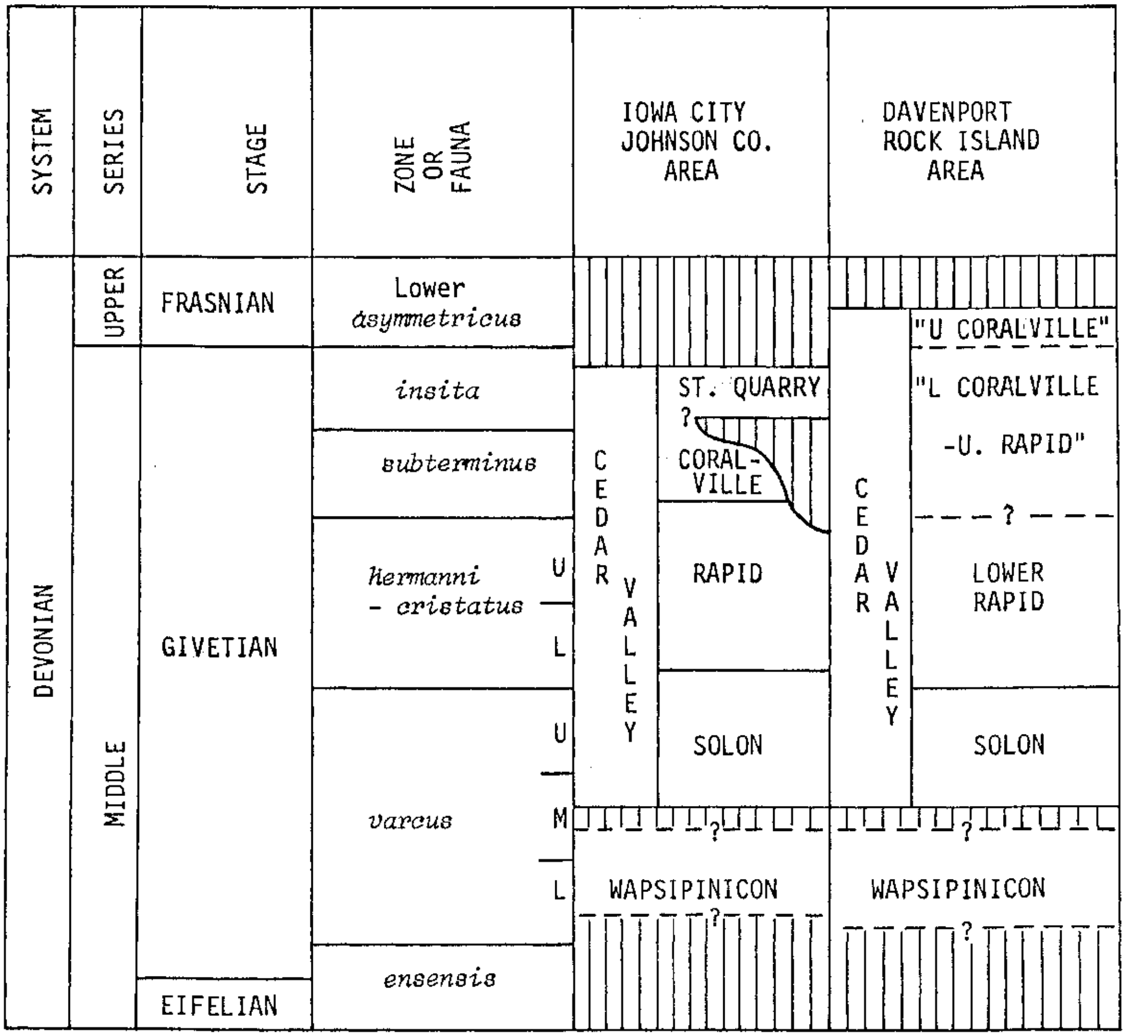

Figure 1. Correlation of the Cedar Valley - State Quarry interval in eastern Iowa with standard Middle and lowest Upper Devonian conodont zones. Between the *hermanni-cristatus* and Lower *asymmetricus* Zones, nearshore conodont biofacies consisting of the *subterminus* and *insita* Faunas are developed in the Cedar Valley sequence.

1.) The *varcus* Zone is identified within the Solon Member (except for the uppermost beds) chiefly on the presence of the nominal species, *Icriodus brevis, Polygnathus ovatinodosus,* and *Ozarkodina semialternans.* The latter two species first occur high in the Middle *varcus* Subzone in Europe, and *O. semialternans* enters near the top of the Tully Limestone (Moravia bed of Heckel, 1973) in New York. This association is found in the lower Solon at Brooks Quarry near Independence, Iowa, and at the Solon type section (sectons 23 and 24, T.81N., R.6W.) in Johnson County (Ziegler et al., 1976, Table 5).

2.) The *hermanni-cristatus* Zone occurs in the uppermost beds of the Solon and the lower part of the Rapid (below the biostromes) Members at the River Products Conklin Quarry (Klapper and Ziegler, 1967, Loc. 22). Klapper and Johnson (1980) formally subdivided the *hermanni-cristatus* Zone into Upper and Lower Subzones. The lower boundary of the Lower Subzone is defined by the first occurrence of *Schmidtognathus hermanni,* and the lower boundary of the Upper Subzone by the first occurrence of *Polygnathus cristatus.* Characteristic species occurring in the Cedar Valley (Klapper & Ziegler, 1967; Ziegler et al., 1976) that first occur in the Lower Subzone are *Schmidtognathus wittekindti* and *Polygnathus limitaris;* whereas *Schmidtognathus peracutus* first occurs in the Upper Subzone. This faunal association is regarded as diagnostic of the zonal assignment indicated, notwithstanding that neither name bearer has yet been found in the Cedar Valley Limestone of Iowa.

3.) The *insita* Fauna is defined by Klapper et al. (1971, p. 300) as the fauna with *Pandorinellina insita* in strata below the first occurrence of *Ancyrodella rotundiloba.* The *insita* Fauna, now recognized as representing a shallow-water biofacies (Sandberg & Poole, 1977, p. 150), was formerly considered as equivalent to the Upper *hermanni-cristatus* Zone and the Lowermost *asymmetricus* Zone (Schumacher, 1976). However, the evidence is not compelling that the oldest part of the *insita* biofacies is a lateral equivalent of the former zone (Johnson, Klapper, and Trojan, 1980, p. 97). Johnson et al. (ibid.) suggested that the oldest part of the *insita* biofacies probably represents an equivalent of the Lowermost *asymmetricus* Zone.

For the most part, the upper part of the Rapid (above the biostromes) and the lower part of the Coralville has yielded a conodont fauna dominated by *Icriodus subterminus* and *Polygnathus xylus* (Klapper, 1975, p. 8). The remainder of the Coralville has thus far proven barren. *I. subterminus* has been recovered in stratigraphic position below the first occurrence of *P. insita* in north-central Iowa (Klug, 1982), northeastern Alberta (Norris and Uyeno, 1983), and southeastern Manitoba (Norris et al., 1982). Within the Johnson County area *P. insita* has only been recovered from the State Quarry Limestone, above the first occurrence of *I. subterminus.* However, in the Davenport-Rock Island area the *insita* Fauna has been recovered from rocks that have been provisionally assigned to the upper Rapid and lower Coralville. The *insita* Fauna in this area is noted to be replaced laterally in the same stratigraphic interval by a different biofacies that is dominated by *I. subterminus* and *P. xylus* (Klapper, 1975). How the interpreted *insita-subterminus* biofacies in the

Davenport-Rock Island area correlates with the stratigraphic position of the *insita* Fauna superjacent to *subterminus* fauna in Johnson County and north-central Iowa (Witzke and Bunker, 1984) is at present unclear.

Given that the *insita* Fauna in the State Quarry Limestone correlates with the Lowermost *asymmetricus* Zone, then the subjacent *I. subterminus* fauna in the upper Rapid (above the biostromes) - lower Coralville interval in Johnson County may correlate with some part of the *disparilis* Zone. However, diagnostic species of the *disparilis* Zone, which is developed in an offshore conodont biofacies, have not been noted in association with the nearshore *I. subterminus* fauna.

4.) The Lower *asymmetricus* Zone is defined on the first occurrence of *Ancyrodella rotundiloba*. *A. rotundiloba* has so far only been recovered from the uppermost exposed bed of the Cedar Valley Formation along Fancy Creek, near Milan, Illinois (Klapper, 1975). According to the recent definition by the International Subcommission on Devonian Stratigraphy, the Middle-Upper Devonian boundary is now placed at the base of the Lower *asymmetricus* Zone (Ziegler and Klapper, 1982).

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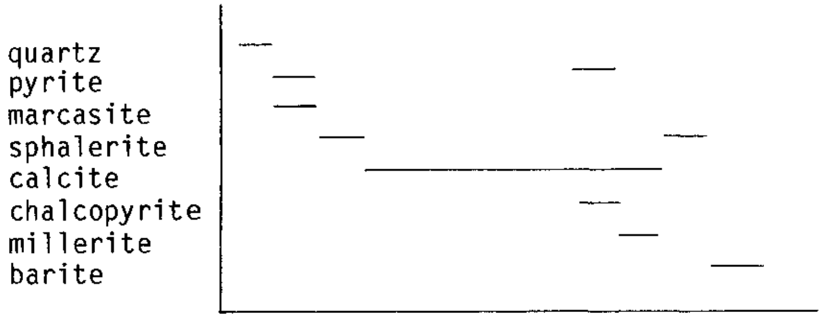
MINERALIZATION AT CONKLIN QUARRY

by Paul L. Garvin, Cornell College

Minor epigenetic mineralization occurs in the Conklin (River Products) Quarry. It has been observed in every stratigraphic unit which has been exposed during the history of quarrying, from Davenport to the Coralville. Pyritic mineralization is also localized in exposures of the Upper Devonian Independence Shale and Pennsylvanian sandstone. The mineralization occurs chiefly as linings and fillings of fractures (joints and minor faults), and solution and breccia cavities. The fractures, which frequently display slickensides, strike generally NE (N32° - 82°E) and dip NW (42° - 80°NW). Solution cavities are generally less than 10 cm across and are widely scattered. Locally, cavities as much as half a meter in length have been observed.

Minerals occurring in the quarry, in order of decreasing abundance, are: calcite, pyrite, quartz, sphalerite, barite, marcasite, millerite, and chalcopyrite. Fluorite and galena, recognized in minor deposits of a similar nature elsewhere in eastern Iowa (Heyl and West, 1982) were not observed at Conklin Quarry. Calcite is commonly euhedral. Crystals, typically of the dogtooth variety, reach 8 cm or more in length. Twinning (basal and rhombohedral) is infrequent; inclusions (millerite, chalcopyrite, and pyrite) are common. Pyrite occurs as small (less than a half centimeter across) cubic and cubo-octahedral crystals and subhedral clusters, generally associated with calcite. In the Independence Shale it is present as single and intergrown cubes up to 3 cm across, and as concretionary masses. In the Pennsylvanian sandstone, resting on the Coralville, pyrite cements sand grains and replaces carbonized woody plant fragments. Quartz occurs as porous ellipsoidal masses reaching 25 cm or more in length and is restricted to the contact between the Solon and Davenport Members. Minor millerite, calcite, and pyrite have been observed in the pores. These quartz masses likely result from the replacement of fossils (oncolites?). Sphalerite is generally massive and is commonly observed as coatings on fracture surfaces of the Solon Member. Barite occurs as transparent to translucent tabular crystals generally less than 2 cm across, and as a fine druse on calcite. The tabular crystals frequently contain inclusions of millerite. Marcasite crystals are typically bladed or wedge-shaped, and generally associated with calcite. Millerite, for which the quarry is famous (Horick, 1974, p. 38), is of capillary habit, with individual needles and "brushes" reaching 5 cm or more in length. Chalcopyrite, which commonly forms the base from which millerite grew, occurs as pseudotetrahedral crystals generally less than 4 mm across.

With regard to paragenesis, in the best observed exposures (Solon and Rapid hosts) calcite is the earliest mineral. In the now-covered north pit (Davenport host) marcasite and sphalerite precede calcite. The pyrite mineralization in the Independence Shale and Pennsylvanian sandstones is likely diagenetic and is not included in the paragenesis. A generalized paragenetic diagram for the quarry follows.



Fluid inclusion analyses were performed by Conveney and Goebel (1983) on sphalerites from the Solon Member. Homogenization temperatures for fourteen primary inclusions range from 74°C to 118°C (ave. 89°C).

All minerals occurring at the Conklin Quarry (CQ) have been observed in Upper Mississippi Valley (UMV) Zn-Pb deposits (Heyl et al., 1959, p. 84). The temperature range of deposition of CQ sphalerite falls within the general range from UMV deposits. Major differences between the CQ deposit and typical UMV deposits are: 1) lack of galena at CQ, and 2) the appearance of calcite fairly early in the paragenetic sequence at CQ (compare Heyl, 1968, p. 449).

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PENNSYLVANIAN STRATA AT CONKLIN QUARRY

by Brian J. Witzke

Pennsylvanian sandstones, mudstones, and conglomerates occur locally within channels incised into the Devonian limestones at Conklin Quarry. In addition, Pennsylvanian sediments were deposited in paleokarst openings within the Cedar Valley limestones, as seen at a few places in the quarry. A Pennsylvanian paleokarst fill within the lower Rapid Member can be seen above the first bench in the eastern face of the main pit at the Conklin Quarry.

The best exposure of Pennsylvanian strata can be seen in the southeast portion of the main pit, where a channel-filling sandstone and mudstone sequence is incised up to 4 m (13 ft) into the Coralville Member of the Cedar Valley Formation (figure 1). As delineated by limestone exposures along the channel margin on top the quarry, the channel trends northwest-southeast. This trend aligns closely with that of the Pennsylvanian channel-filling sequence in the northern part of Iowa City near the Mayflower Dormitory (Witzke and Kay, 1984), and the Conklin and Mayflower channels conceivably may be part of the same ancient channel system. Medium to dark gray mudstone and shale dominates along the channel margins. Thin siltstone and sandstone lenses, in part pyrite-cemented and crossbedded, occur within the mudstone sequence. The mudstone are, in part, laminated, and carbonaceous material, including carbonized wood debris, is noted. A fine to medium-grained sandstone 43 cm (1.4 ft) thick caps the mudstones along the northern edge of the exposure. The central channel area is dominated by fine to medium-grained sandstone. Mudstone clasts are noted in places. Much of the sandstone is poorly consolidated, but some beds are cemented by pyrite or ferric oxides. The sandstones contain scattered to abundant carbonaceous material in stringers or as isolated pieces of carbonized or pyritized woody debris up to 45 cm (1.5 ft) long. Thin stringers of gray silty clay occur with the sandstone, especially ni the lower portion. Crossbedding is apparent in some of the sandstone beds; identifiable cross-sets generally trend to the southeast. Some sandstone beds are faintly laminated.

Plant fossils are common in the Pennsylvanian sandstones in the southeast part of the main pit. In addition, horizontal burrows up to 5 cm (2 in) long are noted on the surfaces of some of the sandstone beds. The bulk of the plant fossils are unidentifiable pieces of woody material. They generally are carbonized or occur as impressions in the sandstones, although the plant material is pyritized locally. Several identifiable plant fossils were collected at this locality that generally confirm a Pennsylvanian age for the deposit. All are from arborescent microphyllophytes of the Order Lepidodendrales. Trunk impressions and leaf scars of *Lepidodendron* and *Sigillaria* are noted. A *Lepidostrobus* cone also was collected. The specimens were examined by Jeffry Schabilion, Department of Botany, University of Iowa, whose assistance is acknowledged.

Other exposures of Pennsylvanian strata in the Conklin Quarry are also noteworthy. Conglomeratic sandstones containing clasts of quartz, chert, and limestone locally occur above Coralville limestones in the old quarry. Pennsylvanian sandstones are accessible beneath the Pleistocene sequence in

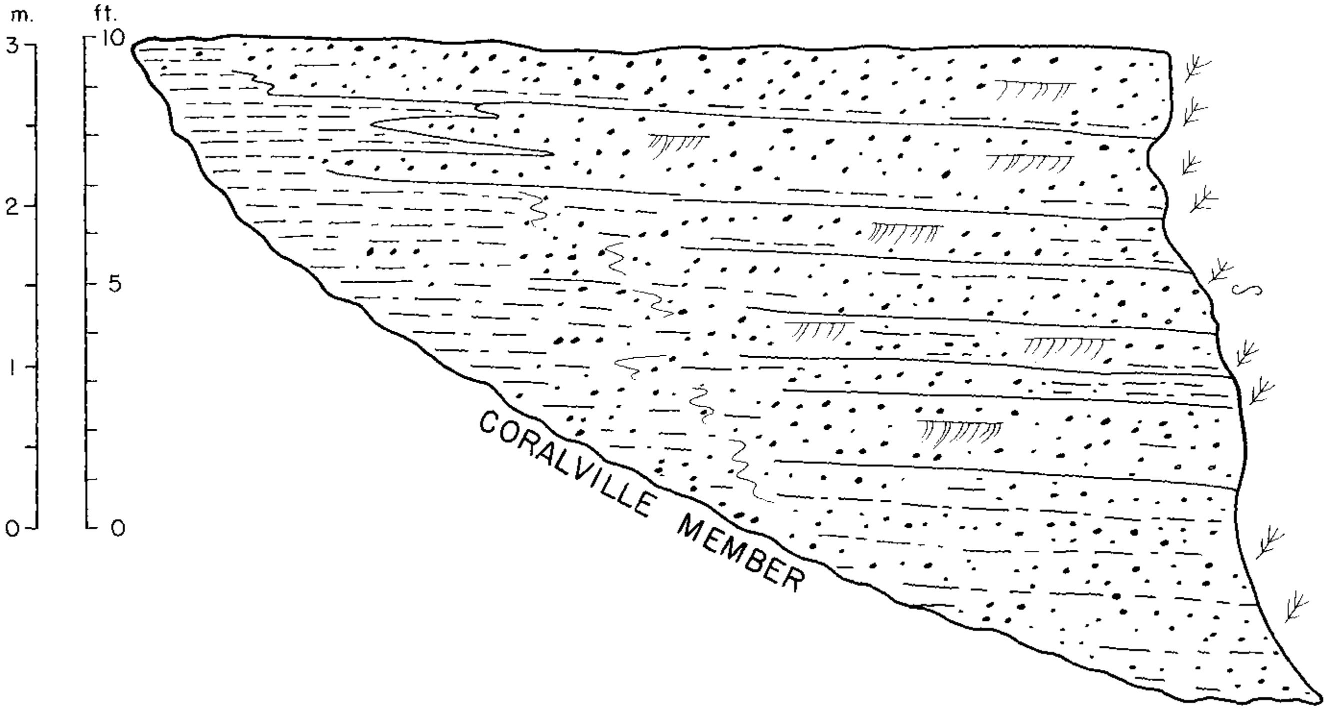

Figure 1. Pennsylvanian channel-filling sequence in southeast portion of main pit, Conklin Quarry.

south-central portion of the main pit. These sandstones occupy a position within a channel incised into the Coralville Member. The sandstones are poorly sorted and commonly include matrix clay. Mudstones also occur. In general, the sandstones are better consolidated than those in the southeast portion of the main pit, and ferric oxide and pyrite cements are noted. Unidentifiable plant debris is common in some beds.

Petrographic study of the Pennsylvanian sandstones at Conklin Quarry remains to be completed. Nevertheless, observations of hand specimens and sand grains are of interest. There appears to be significant compositional differences between the sandstones in the southeast and south-central portions of the pit. The sandstones from the southeast area are dominated by fine or medium-grained, angular to rounded quartz sand, and are moderately well sorted. The sandstones are typically white in color, but locally are stained orange by ferric oxides. The grains commonly exhibit euhedral and subhedral quartz overgrowths. Although point-count analysis has not been completed, quartz grains are clearly dominant; trace amounts of feldspar or other mineral grains may be present. The clean sandstones generally resemble quartzarenites. These sandstones contrast with the "dirtier" sandstones in the south-central part of the pit. Sandstones in that area typically are poorly sorted; fine grains dominate, although medium and coarse grains and silt are present. The matrix is commonly clay-rich. Pyrite and ferric oxide cements are noted. The grains vary from subangular to rounded, but most are subrounded. Quartz overgrowths were not observed. Quartz is the dominant mineral grain. Although petrographic study has not been completed, there appears to be notable component of feldspar and other grains. The contrasting lithologies of the two sandstone types at Conklin Quarry suggest that they may have been deposited at different times.

Paleokarst openings in eastern Iowa were filled with Pennsylvanian sediments as base levels rose in the area. The Conklin Quarry sandstones were deposited in fluvial environments as stream systems aggraded. Channel geometry and crossbedding verify their fluvial origin. Two episodes of Pennsylvanian fluvial sedimentation are documented in the Muscatine area of eastern Iowa (Fitzgerald, 1977): 1) Early Pennsylvanian deposition of Caseyville quartzarenties, and 2) Middle Pennsylvanian deposition of immature feldspathic Spoon sandstones. The sandstones in these two formations apparently had different source areas. The two constrasting sandstone lithologies at the Conklin Quarry may correspond to these two depositional episodes. The feldspathic sandstones in the northern part of Iowa City probably correlate with Middle Pennsylvanian sandstones elsewhere in Iowa (Witzke and Kay, 1984). Additional studies of the Conklin Quarry sandstones will permit more meaningful comparisons.

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NOTES:

THE OVERBURDEN: QUATERNARY STRATIGRAPHY OF THE CONKLIN QUARRY

George R. Hallberg
Chief, Geological Studies, I.G.S.

Timothy J. Kemmis
Research Geologist, I.G.S.

Nyle C. Wollenhaupt
(Formerly, Research Geologist, I.G.S.)
Research Associate, Dept. of Agronomy,
North Dakota State University

Steven P. Esling
(Formerly, Research Assistant,
Dept. of Geology, University of Iowa)
Assistant Professor, Dept. of Geology,
Southern Illinois University at Carbondale

E. Arthur Bettis III
Research Geologist, I.G.S.

Thomas J. Bicki
(Formerly, Research Associate
Dept. of Agronomy, Iowa State University)
Consultant, Smithfield, Rhode Island

INTRODUCTION

The Conklin Quarry operation has exposed one of the thickest, most complete sections of Pre-Illinoian Quaternary deposits in the Midwest. For the past decade the various authors, led by the senior author, have intermittently described and sampled the section as new exposures were made during quarry operations. This guidebook presents a record of that work and notes the continuing research that is in progress. Research at Conklin Quarry has covered a broad spectrum of Quaternary studies including: 1) the stratigraphy and physical characteristics of the deposits; 2) ongoing work on the fabrics and depositional history of the deposits; 3) observations on the 'paleolandscape' relations revealed in cross-section in the exposure; 4) the nature of jointing in unlithified tills and diamictons; 5) the remanent paleomagnetism of the rock units; and 6. a variety of paleontologic investigations. This paper addresses the first 4 items above, while items 5 and 6 are discussed in companion papers in this volume.

Methods, Terminology and Abbreviations

In descriptions of the stratigraphic sections, standard pedologic terminology and horizon nomenclature are used for soils and paleosols (see Soil Survey Staff, 1951, 1975; Guthrie and Witty, 1982). For convenience, enumeration of different materials within a paleosolum begins with the uppermost material in the paleosol, instead of at the landsurface. For the decriptions of the Quaternary sediments other than in the solum or paleosolum, standard weathering zone terminology is used as outlined in Hallberg et al. (1978a, see below). Standard USDA-SCS textural classes and terms are also used (see Soil Survey Staff, 1975; Walter et al, 1978). Laboratory data are presented to quantify the physical characteristics of the materials. Laboratory methods used are (in Hallberg, ed., 1978): particle-size analysis -- Walter et al. (1978); clay mineralogy -- Hallberg et al. (1978b); and analysis of sand-fraction lithology -- Lucas et al. (1978). Matrix carbonate content of the deposits was evaluated using a Chittick apparatus, following the procedures outlined by Walter and Hallberg (1980).

A variety of terms, symbols, and abbreviations are used in the descriptions and discussions in this report. These are common terms which are familiar to most Quaternary workers, but may not be clear to the broader group of geologists included on this field trip. The text below outlines these terms; the references cited provide the basis and definitions for most of the terms.

Weathering Zone Terminology

Standard abbreviations and symbols are used as a shorthand method to describe the 'weathering zones' *below* a soil in Quaternary deposits in Iowa. These terms are defined in reference to the (Munsell) color of the material (related to state and distribution of free-iron oxides and organic matter) and the presence or absence of matrix-carbonate minerals (Hallberg et al., 1978a). The abbreviations are outlined below:

First Symbol - color reference;

O - oxidized
D - 'deoxidized' (used for loess and related materials)
R - reduced (used for till, and related deposits)
U - 'unoxidized'

Second Symbol - leached or unleached state;

U - unleached; primary carbonates present
L - leached; no carbonates detectable (with dilute HCL)
L2 - leached; primary carbonates absent, secondary carbonates present

Modifier Symbols;

M - mottled; refers to zones containing 20-50% contrasting mottles; when used with the unoxidized zone designation it infers 20% or less mottles of reduced colors; precedes first symbol when used.
J - jointed, describes the presence of well-defined vertical joints in the till; joints often show oxidized and reduced colors, often have coatings or rinds of secondary iron-oxides; occasionally other secondary minerals such as calcite or gypsum; second symbol when used.

Examples of described weathering zones:

OL - oxidized, leached--yellowish brown (10YR 5/6) or strong brown matrix, and leached.
MDU - mottled, deoxidized, unleached -grayish brown (2.5Y5/2) matrix with strong brown (7.5YR5/8) mottles and pipestreams, unleached.
RJU - reduced, jointed, unleached--mixed olive (5Y4/4 and 5Y4/3) and very dark grayish brown (2.5Y 3/2), with common gray (5Y5/1) and light olive brown (2.5Y5/4) mottles; prominent vertical joints, with 1 cm strong brown (7.5YR5/8) segregations along the joint; unleached.
UJU - unoxidized, jointed, unleached--uniform dark greenish gray (5GY4/1) matrix, with few thin vertical joints, which have mottled light olive brown (2.5Y5/6) and olive gray (5Y5/2) faces, and a 3 cm rind of greenish gray (5GY5/1); unleached.

Lithofacies Codes

Lithofacies codes are a convenient shorthand to abbreviate lithologic and sedimentologic descriptions of rock units. Descriptive lithofacies codes have been introduced and defined for fluvial deposits by Miall (1977) and for glacial diamictons by Eyles et al. (1983). For this study we will use the basic descriptive codes of Miall (1977) and Eyles et al. (1983) which have been partially revised to include certain features present in the deposits at Conklin Quarry. For use in this report we have additionally defined lithofacies for colluvial deposits and loess that are both genetic and descriptive. The lithofacies codes provide a concise indentification of basic lithologic properties, and are used on various figures and tables. Combined with other descriptive and laboratory data they provide an objective characterization of the Quaternary stratigraphy (in the sense discussed by Kemmis and Hallberg, in press).

The lithofacies codes consist of a series of alphabetic designations. The codes used in this report are:

Code	Lithofacies
G__	Gravel.
S__	Sand, generally medium to coarse with minor gravel component.
Gm_	Matrix supported gravel.
Gc_	Clast supported gravel.
__p	With planar crossbeds.
__s	With cut and fill, or scour structures.
__r	With ripple marks or structures.
F__	"Fines," silt and clay matrix-dominated deposits.
_l_	Laminated, may include thin interbedded sands, small ripples.
_m_	Massive.
_sc	Laminated or thin bedded silts and clays.
C__	Poorly sorted 'colluvium,' slopewash.
FC_	Fine-textured colluvium, and poorly sorted overbank deposits.
L__	Loess.
Lm_	Loess, massive.
Ls_	Loess, crudely stratified with slopewash.
Lse	Loess, interbedded with eolian sand.
D__	Diamicton, poorly-sorted, glacial deposits, such as till.
Dm_	Matrix supported; clasts supported in <2 mm sand, silt, clay fraction; most diamictons in Iowa have <10% clasts.
Dc_	Clast supported.
D_m	Massive, generally structureless, except for vertical joints and (s) features outlined below.
D_s	Stratified, obvious textural differentiation in thin beds; often includes thin beds of Dmm and sands(S) or silts (Fm).
D__(s)	Sheared, shows structures indicative of shearing, generally in subglacial facies; such as overturned folds, low angle thrusts between Dmm and substrate; or block inclusions, smears and smudges, i.e. incorporations of substrate materials which are sheared into thin, yet recognizable masses within the matrix of the diamicton (see Kemmis et al., 1981; Kruger, 1979 for further discussion).
___P	Soil or paleosol developed in unit, pedogenesis has obscured many other sedimentary features.

Both the terms till and diamicton are used in this report. Diamicton is the generic, descriptive term for any unlithified rock that is poorly sorted, and ranges in particle size from clay to boulders. Till is a diamicton, but we will try to use till in the narrow sense of Lawson (1981), i.e., till is a deposit which has inherited its properties directly from glacier ice. Many other diamictons are generated in the glacial environment by resedimentation of till (by gravity or water). Thus, unless the genesis of the deposit can be inferred it will be generically called a diamicton. Most of the diamictons in the Conklin Quarry show evidence of subglacial deposition, and thus are basal tills in the generic sense of Kemmis et al. (1981) and Dreimanis (1976).

Other Abbreviations

Other abbreviations are used on the tables and figures to save space. These will simply be outlined here, and explained later in the report.

LS - Late-Sangamon
LSP - Late-Sangamon Paleosol
LSPT - Late-Sangamon Paleosol, truncated
LSES - Late-Sangamon Erosion Surface
LSPs - Late-Sangamon pedisediment
IES - Wisconsinan Iowan Erosion Surfaces
BL - Basal Loess
BLS - Basal Loess Sediments
BLP - Basal Loess Paleosol
IAC - intra-Aurora contact

REGIONAL SETTING

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

The Pre-Illinoian deposits have been formally classified into the Alburnett Formation and the younger Wolf Creek Formation (Hallberg, 1980a). Both formations consist predominantly of glacial diamictons (till), but include other types of deposits as well. The formations (and their members) are differentiated by various physical and mineralogical characteristics (Hallberg, 1980a,b). Table 1 summarizes the distinct differences in clay mineralogy, which characterize the formations.

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

Table 1. Summary of clay-mineralogy data for the Wolf Creek and Alburnett Formations from eastern Iowa (data from Hallberg, 1980; Hallberg, ed., 1980).

	Clay Mineralogy Ex.	 Ill. %	 K + C
	Wolf Creek Formation (N = 476)		
Mean	61	18	22
s.d.	4	3	3
(range)	(50-74)	(4-24)	(14-34)
	Alburnett Formation (N = 207)		
Mean	43	25	32
s.d.	6	4	4
(range)	(28-51)	(15-35)	(21-48)

Ex. - expandable clays or smectite.
Ill. - illite.
K + C - kaolinite and chlorite.

tinuous, uniform erosion since the last Pre-Illinoian glaciation. There are four sets of surfaces descending from the divide to the valley floor (where parts of all of the surfaces have been preserved): the Yarmouth-Sangamon surface, the Late-Sangamon erosion surface(s), the Wisconsinan-or "Iowan" erosion surfaces, and the alluvial valley floor (Hallberg et al., 1978c; Ruhe, 1969).

The loess-mantled, Yarmouth-Sangamon surface remains as narrow, nearly flat upland divides in this area. The Yarmouth-Sangamon surface is, perhaps, a remnant of the youngest Pre-Illinoian drift plain which was subjected to weathering and local modification until burial by Wisconsinan-age loess. Generally, a thick, gray (poorly drained) soil (now buried) formed in the surficial deposits of this surface. This soil was named the Yarmouth-Sangamon Paleosol (Ruhe et al., 1967) because it was presumed to transgress Yarmouth and Sangamon time.

The Late-Sangamon surface is an erosion surface cut into, and inset below the Yarmouth-Sangamon surface of the primary divides. The break between the Yarmouth-Sangamon and Late-Sangamon surface is marked by topographic, geomorphic, and pedologic discontinuities (Ruhe et al., 1967; Hallberg et al., 1978c). In this area it consists of gently sloping, loess-mantled pediments. Today, only remnants of this erosion surface are present, preserved as a step (level) down along interfluves. In various areas, many elements of the Late-Sangamon landscape may be preserved, from the pediment to the valley-slope fan to the floodplain (Ruhe et al., 1967). Seldom are large segments of this paleolandscape exposed because of the mantle of Wisconsinan loess. After, and in part during, the later stages of cutting of the Late-Sangamon erosion surface, a soil formed, indicating a change to relatively more stable hillslope conditions. This soil, called the Late-Sangamon Paleosol, also continued to develop until buried by the Wisconsinan loesses. Late-Sangamon Paleosols are distinctive. They are generally less weathered, have thinner sola, and are better drained (with generally red to red-brown colors) than Yarmouth-Sangamon Paleosols (Ruhe et al., 1967, Hallberg et al., 1978c, 1980a). The Late-Sangamon Paleosols are typically developed in multiple parent materials: 1) an upper unit of pedisediment--a sediment derived from the erosion of the surface upslope which has been transported down the pediment; 2) a stone line or gravel lag which marks the pediment-erosion surface; and 3) underlying glacial deposits (Ruhe, 1969; Ruhe et al., 1967).

Inset below the Late-Sangamon surface is another erosion surface, the Wisconsinan-or "Iowan" erosion surface. The break between the Late-Sangamon and the "Iowan" erosion surfaces is again marked by topographic, geomorphic, and pedologic discontinuities. In this area the "Iowan" erosion surface consists of short, gently sloping, loess-mantled pediments which are generally shorter in length than the Late-Sangamon pediments. Again, only remnants of the Wisconsinan- or "Iowan" erosion surface are present, preserved as steps or levels down the interfluves. The "Iowan" erosion surface represents a renewed period of relatively rapid downcutting. It is again marked by a stone line or gravel lag which caps the pediment-erosion surface and by a thin increment of overlying pedisediment. This erosion surface was being cut during the period of Wisconsinan loess deposition in Iowa. This is evidenced both by younger radiocarbon dates at the base of the loess on the "Iowan" surfaces in this area when compared to those on the Yarmouth-Sangamon and Late-Sangamon surfaces and by the thinner increment of loess on the "Iowan" surface (Ruhe et al., 1968; Hallberg et al., 1978c). Loess was continuously being deposited on the relatively "stable" Yarmouth-Sangamon and Late-Sangamon surfaces while early increments of loess were eroded away along with the older deposits in lower portions of the landscape as the "Iowan" erosion surface was actively being developed. During deposition of the Wisconsinan loess, the "Iowan" erosion surface stabilized and the last increment of loess was deposited on it. No buried soil is found on this surface. Erosion was great enough to remove all of the Late-Sangamon or Yarmouth-Sangamon Paleosols which might have been present. A soil was not formed on this erosion surface in this area because it was immediately buried by loess after stabilization.

Most of the literature on the Wisconsinan, or "Iowan" erosion surface refers to these areas as the "Iowan surface" (Ruhe et al., 1968; Prior, 1976), "Iowan Erosion Surface" (Ruhe, 1969; Hallberg et al., 1978c), and "Early Wisconsin pediment" (Ruhe et al., 1967). In fact, this "surface" actually consists of a set of surfaces or levels of similar geomorphic and stratigraphic setting (Fenton, 1966; Ruhe, 1969; Hallberg et al., 1978c); i.e., there are often multiple levels or pediments associated with this general period of erosion.

A final episode of downcutting down to the Holocene alluvial valley has occurred since deposition of the Wisconsinan loess. The alluvial valleys also consist of a series of multiple levels; often subtle terrace surfaces of different age.

In different areas of the state different surfaces may dominate the landscape (Hallberg et al., 1980a, b; 1978c; Ruhe, 1969). In much of east-central and southern Iowa the loess-mantled Late-Sangamon surface is dominant. The Conklin Quarry exposure reveals a cross section of an interfluve on the Late-Sangamon pediment. Such exposures are not only rare, but generally short-lived. Thus, the exposure offers an unusual opportunity to see and study a segment of this ancient landscape.

QUATERNARY STRATIGRAPHY

The Quaternary stratigraphic succession exposed in Conklin quarry has varied through time with quarry operations. Figure 1 summarizes the stratigraphy exposed during two periods, the present (1983-84) and 1975-76, when the most complete stratigraphic successions were exposed. The present exposure is at least 50 to 100 m south of the 1975-76 exposure.

At Conklin quarry, the Quaternary sequence is comprised largely of various complex units of the Pre-Illinoian Alburnett and (younger) Wolf Creek Formations. Various unconformities and paleosols occur within these formations. The Wolf Creek Formation deposits have been variously truncated by development of Late-Sangamon and Wisconsinan subaerial erosion surfaces. Wisconsinan loesses mantle these erosion surfaces and occur at the present land surface.

Section 1 (figure 1) is the section we will walk through to begin the field trip. Nearly 30 m of Quaternary deposits are exposed. An abbreviated description for Section 1 is given in Table 2, while figure 2 shows a summary of the stratigraphy and particle-size data for the section. Table 3 summarizes the laboratory data.

Table 4 presents an abbreviated description and laboratory data for a principal section described in 1976. Table 5 summarizes data from miscellaneous samples collected between 1974 and 1980. Table 6 presents a statistical summary of the particle-size and clay-mineralogic data for the various till units.

Alburnett Formation

Multiple diamictons ("tills") are found regionally in the Alburnett Formation (Hallberg, 1980a), but no consistent means of correlating these individual units has been found. Thus, no members have been formally defined. The Alburnett units have a distinctive clay mineralogy which allows separation from the younger Wolf Creek Formation (see Table 1). At the Conklin Quarry, the Alburnett Formation shows somewhat lower smectite (expandable clay) percentages (37%) and higher kaolinite (37%) than regionally (Table 6).

At Conklin Quarry, the Alburnett Formation consists of two diamicton units (tills) and two fluvial units. One fluvial unit occurs at the top of the sequence and the other separates the diamicton units.

The lowermost diamicton unit is the basal Alburnett Formation deposit in the quarry. It is a thin (generally 1 to 2 m thick), complex unit best preserved in lows on the bedrock surface (Tables 2 and 4; figures 1 and 2). The character of the unit varies with local bedrock substrate lithology and with height above the bedrock surface. Where the unit overlies the Devonian Cedar

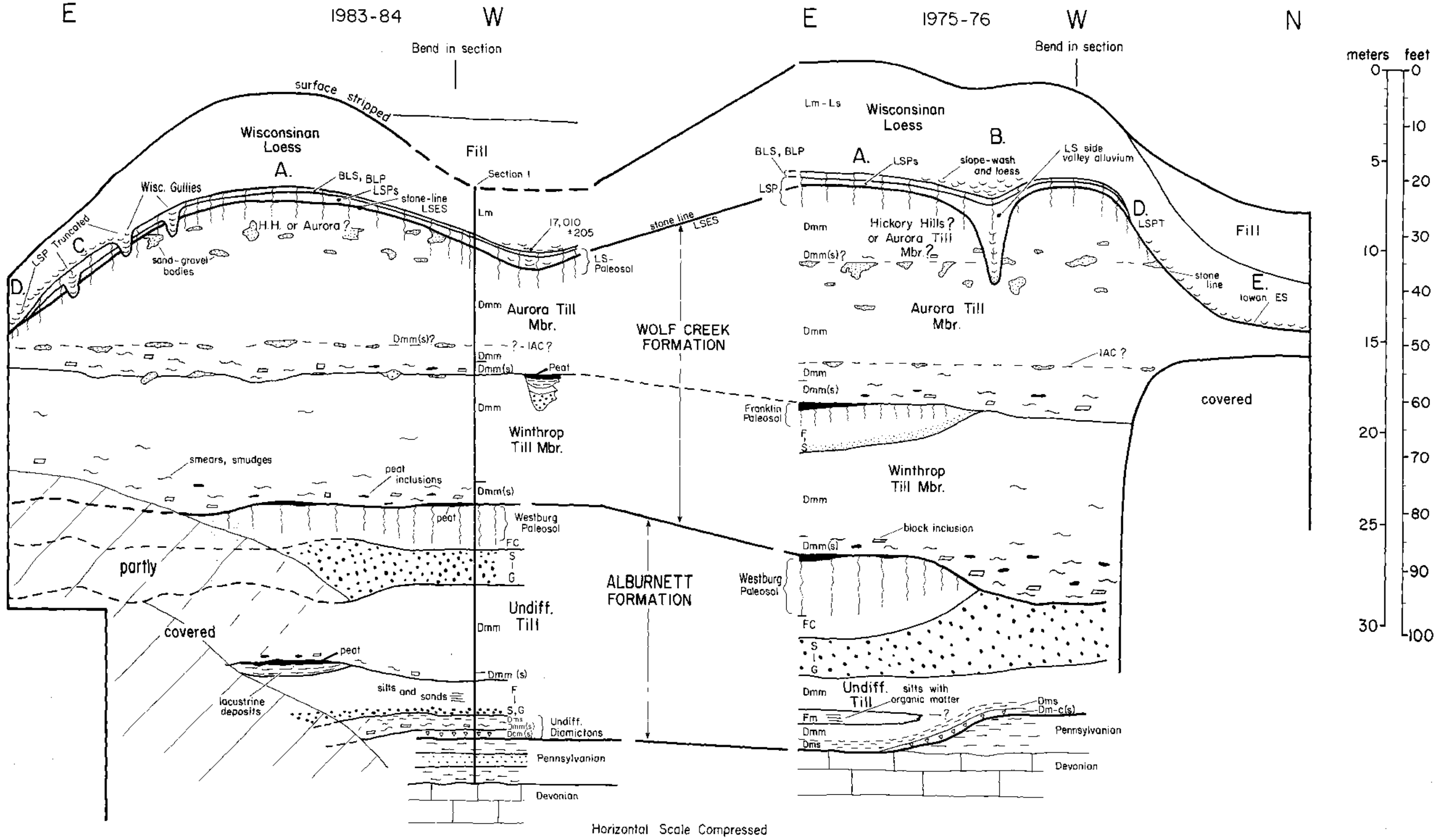

Figure 1. Schematic overview of Quaternary stratigraphy and sedimentological features in the Conklin Quarry.

Table 2. Abbreviated description for Section 1; Quaternary stratigraphy, Conklin Quarry.

FEET (meters)	
	WISCONSINAN Loess (Lm)
0 - 5.1 (0 - 1.6)	Fill; truncated soil and OL loess, silt loam.
5.1 - 8.6 (1.6 - 2.6)	DU loess, Silt loam, with snail shells (Lm).
8.6 - 9.5 (2.6 - 2.9)	OL loess, Silt loam, weakly calcareous locally (Lm).
	Basal loess sediments (BLS) Basal loess paleosol (BLP)
9.5 - 9.8 (2.89 - 2.98)	Ab; 10YR 3/2, dark grayish brown, heavy silt loam; charcoal flecks (CP).
	Late - SANGAMON PEDISEDIMENT (LSPs) Late - Sangamon Paleosol (LSP)
9.8 - 10.6 (2.98 - 3.23)	A/Eb; silty clay loam to loam; platy; charcoal flecks (CP).
10.6 - 11.6 (3.23 - 3.54)	B1tb; strong brown to reddish brown heavy clay loam (CP).
11.6 - 12.1 (3.54 - 3.69)	B2tb; strong brown to reddish brown clay; stone-line at base (CP).
	PRE-ILLINOIAN WOLF CREEK FORMATION (Aurora Till Member)
12.1 - 14.1 (3.69 - 4.30)	B3tb; reddish brown, clay, to heavy clay loam; till (DmmP).
14.1 - 16.1 (4.30 - 4.90)	B4tb; strong brown, to reddish brown heavy clay loam; till (DmmP).
16.1 - 17.1 (4.90 - 5.21)	C-MOJL heavy loam till (Dmm).
17.1 - 17.6 (5.21 - 5.36)	MO-RJL2 loam till, with large carbonate concretions (Dmm).
7.6 - 19.6 (5.4 - 6.0)	MO-RJU2 loam till(Dmm); with large carbonate concretions, in matrix and joints; numerous deformed sand and gravel (S,G) inclusions from 12 to 19.6 feet laterly from this section; in places till seems deformed (Dmm(s)) around s & g bodies. Locally paleosol developed in sand and gravel. Laterally, to east (100 feet) on exposure the Late-Sangamon surface rises in eleva-tion and there is about 8 feet of (light loam) till above sand and gravel zone. This zone may mark break between Hickory Hills and Aurora Till Members, or may be intra-Aurora subdivision (below or within 19-22 foot zone).
19.6 - 21.6 (6.0 - 6.6)	MO-RJU2 till (Dmm), as above, but few sand lenses.
21.6 - 28.1 (6.6 - 8.6)	MRJU loam till (Dmm).
28.1 - 33.8 (8.6 - 10.3)	MUJU loam till (Dmm).
NOTE:	28.1 -33.8 ft. horizon, MUJU loam till, -Aurora Till Member; in this horizon occurs a discontinuous zone of water seepage and thin (0.1-1.0 ft) discontinuous sand and gravel lenses; till (Dmm(s)) shows pronounced fissile parting around some of these lenses, and in zones between lenses, providing discontinuity for seepage; some minor oxidation (MRJU) occurs around sand lenses. This zone is continuous for over 250 feet laterally; likely till-till contact within Aurora T.M. (IAC in diagram; Intra-Aurora Contact).
33.8 - 36.3 (10.3 - 11.1)	UJU loam till (Dmm(s)); 5Y 3/2 and 5GY 4/1. Lower 2 to 5 feet with block inclusions, sheared inclusions, smudges of underlying till, peat, sand and silt lenses. A few deformed sand lenses at lower contact may be related to this till. Contact varies laterally from abrupt till -till contact, to till over sand or silt inclusions. Lower boundary described at abrupt till -till contact. About 5 feet relief on contact.

Table 2 con't.

Winthrop Till Member

36.3 - 40.3 (11.1 - 12.3)	MR -MOJU heavy loam till (Dmm); mixed -2.5Y 4/2, 2.5Y 4/1, 10YR 5/4; mottles and along joints 10 YR and 7.5 YR 4/6, 5/4, 5/6-8. Joints generally continue from one till to next, some deflect in vertical attitude at contact. Locally, preserved swales on the Winthrop surface show Aurora till over 3 feet of peaty silt (Oeb), over 1 foot of mucky silt loam (Ab), over 2 to 3 feet of RL to RU sandy loam(S) and thinly-bedded silt loam (F); inset in steep-sided swale or gully (?) in MRU Winthrop Till. This is a "facies" of the Franklin Paleosol; a weakly developed O/A/C profile.
40.3 - 42.8 (12.3 - 13.0)	MRJU loam, till (Dmm).
42.8 - 56.8 (13.0 - 17.3)	MR - MUJU loam till (Dmm).
56.8 - 58.2 (17.3 - 17.7)	MR -MUJU heavy loam till (Dmm(s)); with sheared inclusions and smudges, of underlying paleosol (Ab) and wood; abundant smudges of Pennsylvanian mudstone. (Some MOJU around inclusions.) Abrupt lower boundary where described.

ALBURNETT FORMATION
Westburg Paleosol (developed in undifferentiated alluvial deposits)

58.2 - 59.7 (17.7 - 18.2)	Ab and A/Bb, 5Y 2/1 -N20; mucky silty clay loam to clay loam (FCP); compressed; in some areas soil structure deformed into massive sheared blocks; locally wood and thin (0.5 feet) fibrous peat at upper contact. Wood previously identified as spruce.
59.7 - 62.2 (18.2 - 19.0)	Btgb; silty clay (FCP); mottled 5Y 3-4/1, 56Y 4/1.
62.2 - 64.4 (19.0 - 19.6)	Btgb; as above, heavy silty clay loam, to clay loam (FCP).
64.4 - 65.8 (19.6 - 20.1)	Btgb; as above, clay loam (FCP), abrupt lower contact.
65.8 - 66.9 (20.1 - 20.4)	Btb -(Beta B?); MRL; 2.5Y 5/3 sandy clay loam sediments (FC-SP).
66.9 - 72.5 (20.4 - 22.1)	OL; stratified sand, sandy loam, with some fine gravel; abrupt lower contact; coarse, clast supported, gravel at till contact (Sp grading to GCp).

ALBURNETT FORMATION
Till, undifferentiated

72.5 - 73.0 (22.1 - 22.3)	UL, loam till (Dmm).
73.0 - 76.0 (22.3 - 23.2)	UU loam till (Dmm).
76.0 - 84.5 (23.2 - 25.8)	UU-UJU loam till (Dmm).
84.5 - 87.7 (25.8 - 26.7)	MUJU - MRJU, very dense, hard loam till (Dmm).
87.7 - 88.5 (26.7 - 26.9)	MRJU, till (Dmm(s); fissile, medium to thick platy, with Fe oxide stains on plates; abrupt lower contact with stratified deposits; few inclusions of sands from below.

Stratified Sands and Silts (Fl-Fsc and Sp)

88.5 - 90.0 (26.9 - 27.4)	Interbedded MUU -UU silts, and MR-MOU sands; deformed below till contact up to 2.5 feet; shear structures with thrusts, etc, overturned folds; generally overturned from north to south.
90.0 - 93.3 (27.4 - 28.4)	Thinly bedded to laminated UU-MUU silts and silt loam, some organic rich beds.
93.3 - 93.7 (28.4 - 28.6)	Sand, OU, medium grained, massive.
93.7 - 94.0 (28.6 - 28.7)	MRU, diamicton, with thin sand and silt stringers.
94.0 - 94.3 (28.7 - 28.8)	MOU, sand, medium, massive.
94.3 - 94.5 (28.8 - 28.8)	OU, iron-oxide cemented sandy loam with gravel, 5YR 6/4; (Gms); lag on diamicton below; gravel is matrix supported; matrix sometimes silt loam; pebbles angular.

Table 2 con't.

NOTE: Laterally (to east) the interbedded silts and sands grade (? or are angularly truncated by) into more sand-dominated facies; beds of medium sand, with climbing ripples 0.8-1.5 feet thick.

Also, to east, overlying till rises in elevation (2-3 feet) and more of the water-laid section is preserved. About 200 feet east of measured section S. Rhodes section shows:

ALBURNETT FORMATION
Till, undifferentiated

Feet (meters)	
0 - 2 (0 - 0.61)	MU-MRJU till (Dmm(s)); fissile, with numerous inclusions of underlying peat, and other sediments.

Peat and Lacustrine Sediments

2 - 2.5 (0.61 - 0. 76)	Compressed peat, oxidized at base.
2.5 - 3.0 (0.76 - 0.91)	Locally 0.2-0.5 feet of MRU massive silt loam.
3.0 - 4.2 (0.91 - 1.28)	MUU-UU light silty clay loam "marl;" highly effervescent; abundant shells and organic matter.
4.2 - 6.0 (1.28 - 1.83)	MUU silts and MOU sands; deformed by load structures.

The thickness of these units vary; the lacustrine package appears to be inset in a broad swale in the fluvial sands and silts. The "shelly" silty clay loam pinches out to the west; the peat is truncated to the west as the till declines in elevation. At this section the total lacustrine-fluvial sequence is about 11-12 feet thick, but still overlies the diamicton, described below, at the main section to the west.

Diamicton Undifferentiated

94.5 - 95.5 (28.8 - 29.1)	MUJU, loam diamicton (Dms), upper portion with thin silt loam partings.
95.5 - 96.0 (29.1 - 29.3)	Yellowish red (5YR 5/6), OU, loam diamicton (Dms-Dmm(s)); partially iron cemented; erratic pebbles and many cobbles of Pennsylvanian substrate; abrupt lower contact; yellowish red color may be derived from Pennsylvanian; this "color band" locally is absent, or is present as inclusion in UU till.

"Deformation" till (Dcm(s);
Glacially deformed Pennsylvanian rocks.

96.0 - 97.2 (29.3 - 29.6)	Deformed, slickensided, sheared, noncalcareous diamicton; mudstone-shale matrix, with angular clasts of sandstone and shale; a few erratics; locally, angular, clast supported diamicton -"deformation till" (Dcm(s).

PENNSYLVANIAN
Undifferentiated

97.2 - 98.2 (29.6 - 29.9)	Brown, cemented, noncalcareous, fine-grained sandstone.
98.2 - 103.7 (29.9 - 31.6)	Poorly indurated, gray, noncalcareous, shaley mudstone and siltstone; lower contact clear but poorly exposed.

* See introduction for abbreviations.

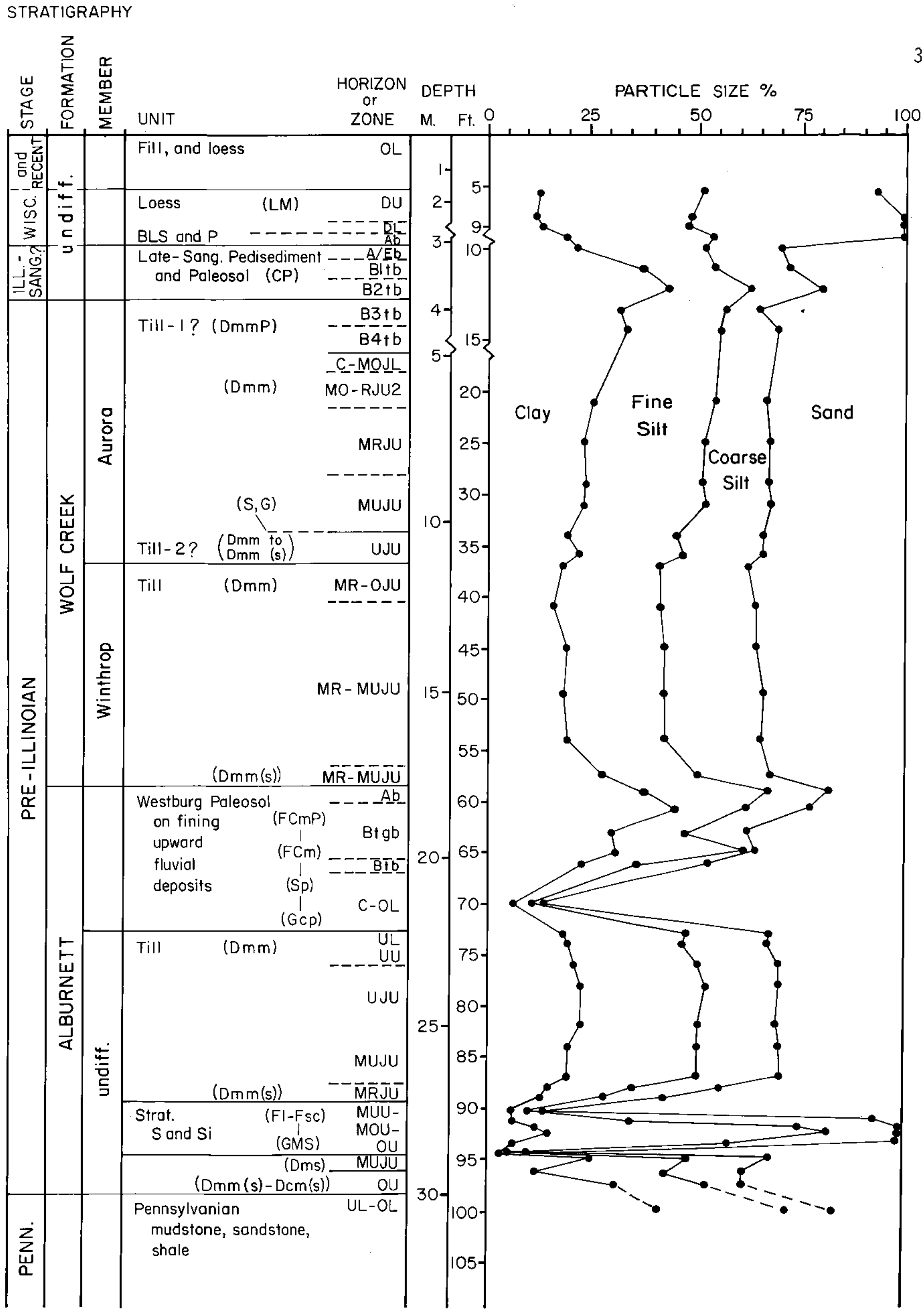

Figure 2. Stratigraphy and particle-size data, Section 1, Conklin Quarry.

Table 3. Particle size and clay mineralogy data for 1983-4 Conklin Quarry Pleistocene section.

Depth		Horizon	%				Clay Mineralogy %		
m	(feet)	or zone	Clay	Fine Silt	Coarse Silt	Sand	Ex.	Ill.	K + C
WISCONSINAN LOESS									
1.8	(5.8)	DU	12.8	37.5	39.9	9.8			
2.4	(8.0)	DU	11.9	37.1	51.6	0.6			
2.7	(9.0)	DU-DL	12.8	34.1	52.3	0.8			
Basal-loess sediments (BLS)									
Basal-loess paleosol (BLP)									
2.9	(9.6)	A/Eb	18.9	33.7	46.6	0.8			
Late-SANGAMON Pedisediment (LSPs)									
Late-SANGAMON Paleosol (LSP)									
3.1	(10)	Eb	21.1	29.7	18.4	30.8			
3.4	(11)	B1tb	37.1	15.8	18.3	28.8			
3.6	(11.8)	B2tb	42.2	19.5	17.7	20.6			
(Stone-line at base of unit)									
PRE-ILLINOIAN									
WOLF CREEK FORMATION									
Aurora Till Member									
3.9	(13.0)	B3tb	36.8	18.6	14.0	30.6			
4.6	(15.0)	B4tb	34.2	20.7	13.3	31.8			
6.4	(21)	C-MO-RJU2	26.0	27.2	12.3	34.5	60	20	20
							(trace vermiculite)		
7.6	(25)	MRJU	24.1	26.5	17.0	32.4	59	20	21
8.8	(29)	MRJU	24.8	25.6	17.3	32.4	57	21	22
9.5	(31)	MRJU	24.6	26.3	17.1	32.0			
(Intra-Aurora Till-Till Contact?)									
10.4	(34)	UJU	18.7	24.9	21.1	35.3	64	15	21
10.9	(36)	UJU	22.7	22.8	20.2	34.3	66	14	20
Winthrop Till Member									
11.1	(36.4)	MR-OJU	18.0	22.2	22.6	37.2	64	17	19
12.5	(41)	MRJU	15.7	24.7	23.0	36.6	60	20	20
13.7	(45)	MR-UJU	19.4	22.2	22.3	36.1	62	16	22
16.5	(54)	MR-UJU	19.3	22.1	23.0	35.6	56	19	25
(Winthrop with sheared inclusions of substrate)									
17.7	(58)	MR-UJU	27.2	22.4	17.4	33.1	60	19	21
ALBURNETT FORMATION									
Undifferentiated fluvial deposits									
Westburg Paleosol									
17.8	(58.4)	A/Bb	37.4	28.3	14.5	19.8			
18.3	(60)	Btgh	43.4	15.9	16.8	24.0	(67)	(13)	(20)
19.2	(63)	Btgh	29.7	15.1	15.6	39.6	Weathered; broad smectite; trace vermiculite; little illite apparent.		
19.8	(65)	Btgb	30.8	27.7	4.4	37.1			
20.1	(66)	Btb	22.2	13.5	16.0	48.3	(49)	(12)	(39)
21.3	(70)	OL	6.8	4.2	2.9	86.1			
Till Undifferentiated									
22.6	(74)	UU	17.1	28.9	20.5	33.5	34	30	36
22.9	(75)	UU	18.5	27.3	20.1	34.1	38	24	38
23.2	(76)	UU	20.2	28.9	19.8	31.0			
23.8	(78)	UJU	22.2	28.9	18.0	31.9	39	25	36
25.0	(82)	UJU	22.4	26.5	18.2	32.9	36	28	36
25.6	(84)	UJU	19.0	29.4	19.9	31.7	32	30	38
26.5	(87)	MUJU	18.3	30.5	20.0	31.2	40	24	36
(Till with sheared inclusions)									
26.8	(88)	MR-	13.9	20.1	19.8	46.2	36	28	36
26.9	(88.4)	MUJU	12.9	14.8	13.9	58.4			
Stratified Sands and Silts									
27.0	(88.6)	MOU	5.9	3.1	3.9	87.1			
27.1	(88.7)	MUU	6.5	23.5	62.5	7.5	29	22	56
27.4	(90)	UU	6.6	27.9	58.0	8.0	34	21	45
27.7	(91)	UU	11.1	61.4	26.7	0.7	32	18	50
28.0	(92)	UU	14.1	64.9	20.6	0.5	33	20	47
28.4	(93)	UU	6.8	48.9	42.7	1.6	34	22	44
28.7	(94.1)	OU	2.3	0.1	6.0	91.6			
Diamicton Undifferentiated (stratified)									
29.0	(95)	MUJU	24.4	22.3	19.0	34.3	42	25	33
(with yellowish-red Pennsylvanian inclusions)									
29.2	(95.8)	OU-UU	11.1	27.3	18.3	40.3	--	(41)	(59)
								trace chlorite	
(Diamicton-Deformed Pennsylvanian)									
29.4	(96.5)	UL-UU	30.3	19.9	9.2	40.6	--	(45)	(55)
								trace chlorite	
PENNSYLVANIAN									
Undifferentiated Mudstone									
30.2	(99)	UL	39.3	31.5	11.1	18.1	--	(42)	(58)
								trace chlorite	
(Samples taken laterally from main section; see text for explanation.)									
WOLF CREEK FORMATION									
Aurora or Hickory Hills Till Member?									
		OL	19.6	16.8	14.4	49.2	64	16	20
		OL	18.7	20.6	15.0	45.7	64	16	20
		OJL	19.9	17.9	15.8	46.4	62	17	21
		MOJL	20.2	21.3	18.5	40.0	68	14	18

Table 4. Abbreviated section description and laboratory data for Conklin Quarry section described in 1975-76.

Depth		Horizon or zone (Sample depth - m)	Litho-Facies	%			Clay Mineralogy %			Matrix Carbonates %				Sand-Fraction Litho				
m	(feet)			Clay	Silt	Sand	Ex.	Ill.	K + C	CA	DO	TC	C/D	C/D	TC	SH	TS	TNS
WISCONSINAN LOESS																		
00.0-01.2	(00.0-04.0)		(Lm)															
		Solum partially stripped surface; Downs soil																
01.2-03.1	(04.0-10.0)	OL	(Lm)															
		(01.4)		18.3	81.0	0.7	72	17	11									
		(03.1)		19.9	79.6	0.5	74	16	10									
03.1-03.7	(10.0-12.0)	OL2	(Lm)															
04.3-04.9	(14.0-16.2)	MOU	(Lm-Lss)															
		(04.6)		11.7	78.5	9.8	73	16	11									
04.9-06.0	(16.2-19.7)	MD-DU	(Lm)															
		(05.0)		18.3	77.6	4.1	73	16	11									
		(05.5)		18.9	80.6	0.5	68	22	10									
06.0-06.2	(19.7-20.2)	MDL (or very weakly calcareous)																
		(06.1)	(Lm)	19.4	77.6	3.0	71	19	10									
		Basal-loess sediments (BLS)																
		Basal-loess paleosol																
06.2-06.4	(20.2-21.0)	Eb	(L-CmP)															
		(06.3)		21.4	61.5	17.1	67	18	15									
							(trace vermiculite)											
Late-SANGAMON Pedisediment Late-SANGAMON Paleosol																		
06.4-06.7	(21.0-22.0)	Etb	(CmP)	29.1	47.2	23.7	(45)	(16)	(39)									
		(06.5)					(weathered; broad smectite; little illite; trace vermiculite)											
PRE-ILLINOIAN WOLF-CREEK FORMATION Aurora or Hickory Hills Till Member?																		
06.7-08.0	(22.0-26.2)	Btb	(DmP)	52.1	20.5	27.4	(cannot calculate, no illite apparent)											
		(07.1)																
08.0-08.3	(26.2-27.2)	MOJL	(Dmm)	30.3	34.6	35.1	62	14	24									
		(08.2)																
08.3-10.4	(27.2-34.7)	MOJL2	(Dmm)															
		(08.4)		24.2	32.2	43.6	70	15	15									
		(10.0)		21.8	32.6	45.6	65	16	19									

Table 4. (Cont'd)

Depth m	Depth (feet)	Horizon or zone (Sample depth - m)	Litho-Facies	% Clay	% Silt	% Sand	Clay Mineralogy % Ex.	Clay Mineralogy % Ill.	Clay Mineralogy % K + C	Matrix Carbonates % CA	Matrix Carbonates % DO	Matrix Carbonates % TC	Matrix Carbonates % C/D	Sand-Fraction Litho C/D	Sand-Fraction Litho TC	Sand-Fraction Litho SH	Sand-Fraction Litho TS	Sand-Fraction Litho INS
10.4-11.0	(34.7-36.2)	MO-MRJU2	(Dmm)															
		(10.8)		20.0	38.7	41.3	60	19	21	2.0	0.3	2.3	6.7	1.4	12	2	14	86
11.0-12.3	(36.2-40.2)	MR-MUJU	(Dmm-															
		(11.1)	Dmm(s))	18.4	34.9	46.7	64	17	19	2.3	2.4	4.7	1.0					
		(12.0)		17.9	32.0	50.0	65	17	18					NC	22	1	23	77
		From 11 to 14m a series of discontinuous sand and/or gravel lenses occur; some are massive, some show cross-bedding; many are deformed and locally till or diamicton appears deformed around these lenses; the lenses vary from 0.1 to 2m in thickness and from 0.5 to 2.5m long. Some sand bodies have flat upper surfaces, with fissile or platy till (Dmm(s)) above the flat surface, for 0.1 to 0.3m. Between sand bodies, locally there is an apparent, abrupt till-till contact between MUJU till, above, and MR-MOJU till below; in other areas there is simply a diffuse color change. Vertical joints continue across contact, and color-related weathering zones are complex, related to variable oxidation around joints and sand bodies. This zone may mark a contact between two different tills; either the Hickory Hills Till Member and the Aurora Till Member, or two tills within the Aurora Member. See text and figures for explanation.																
		Aurora Till Member																
12.3-14.1	(40.2-46.2)	MO-MRJU	(Dmm-Dmm(s) and GSM)															
		(12.6)		22.0	37.9	40.1	65	18	17					--	30	--	32	68
		(14.0)		22.4	43.3	34.3	67	15	18	5.7	8.5	14.2	0.67					
14.1-15.0	(46.2-49.2)	MO-MRJU	(Dmm)															
		(14.4)		22.1	46.5	31.4	65	17	18	4.3	7.8	12.1	0.55	--	29	--	32	68
15.0-16.5	(49.2-54.0)	MRJU	(Dmm)															
		(16.0)		21.1	40.2	38.7	67	14	19									
		Thin discontinuous sand lenses, 0.1 to 0.3m thick occur across the exposure (over about 40m) at this horizon. See text.																
16.5-17.4	(54.0-57.0)	MR-MUJU	(Dmm)															
		(16.8)		20.4	41.7	37.9	66	15	19									
		(17.1)		21.2	41.9	36.9	70	14	16					--	32	--	32	68
17.4-18.6	(57.0-61.0)	MRJU	(Dmm(s))	(Till with common smears, smudges and block inclusions of underlying strata)														
		(18.0)		25.0	42.0	33.0	72	13	15					1.5	35	1	36	64
		(18.5)		30.0	37.5	32.5	57	18	25									
		Undifferentiated alluvial sediments; fining upward, crudely stratified deposits, with a paleosol (locally preserved) in upper portion; laterally the paleosol and entire sequence wedge out, and/or are truncated by overlying till. See text for details.																

Table 4. (Cont'd)

Depth		Horizon	Litho-	%			Clay Mineralogy %			Matrix Carbonates %				Sand-Fraction Litho				
m	(feet)	or zone	Facies	Clay	Silt	Sand	Ex.	Ill.	K + C	CA	DO	TC	C/D	C/D	TC	SH	TS	TNS
		Franklin Paleosol																
18.6-19.0	(61.0-62.5)	Oe-Oab	compressed, brittle, peat and peaty silt (few corroded spruce and chenopod pollen grains identified by pollen analysis)															
19.0-19.3	(62.5-63.2)	Ab	(FCMP)															
		(19.1)		34.4	53.9	11.7	(54)	(26)	(20)									
							(weathered, broad smectite; trace vermiculite)											
19.3-19.7	(63.2-64.7)	Bwgb	(FCMP)															
		(19.3)		32.1	55.4	12.5	61	18	21									
		(19.5)		25.5	46.5	28.0												
19.7-20.2	(64.7-66.2)	C-MRL	(FmCm)	(crudely stratified to massive loamy sediments)														
		(19.8)		18.9	21.1	60.0	53	19	28									
		(20.1)		11.4	40.8	47.8	62	18	20									
20.2-21.1	(66.2-69.2)	MRL	(Fm)	(stratified silts)														
		(21.0)		12.3	79.6	8.1	66	12	22					--	--	--	2	98
21.1-21.4	(69.2-70.2)	OL	(Sm)	(sand, few pebbles)														
		(21.2)		11.2	10.4	78.4												
	WINTHROP TILL MEMBER																	
21.4-22.6	(70.2-74.2)	MRJU	(Dmm)															
		(21.5)		25.0	33.8	41.2	68	15	17									
		(22.0)		24.1	38.5	37.4	68	14	18									
22.6-23.8	(74.2-78.2)	MO-MRJU	(Dmm)															
		(23.2)		23.2	41.9	34.9	63	15	22									
		(23.7)		23.2	39.1	37.7	69	13	18					4.7	34	4	39	61
23.8-26.0	(78.2-85.2)	MR-MUJU	(Dmm)															
		(24.2)		23.6	39.6	36.8	63	12	25	4.9	9.3	14.2	0.53					
		(25.6)		22.2	50.9	26.9	60	19	23					--	18	1	22	78
26.0-26.9	(85.2-88.2)	MR-MUJU	(Dmm(s))	(till with common smears, smudges and block inclusions of underlying strata)														
		(26.5)		38.8	36.5	24.7	63	14	23					--	12	2	15	85
	ALBURNETT FORMATION																	

Undifferentiated alluvial deposits; fining upward, crudely stratified sequence; lower part, planar sets of cross-stratified sand and gravel; with a morphologically well-developed paleosol in upper portion; laterally upper part of sequence eroded and truncated, and overlying Winthrop Till Member lies directly on sand and gravel, described below. See text and 1983-84 descriptions and additional data.

Table 4. (Cont'd)

Depth m	Depth (feet)	Horizon or zone	Litho-Facies	% Clay	% Silt	% Sand	Clay Mineralogy % Ex.	Clay Mineralogy % Ill.	Clay Mineralogy % K + C	Matrix Carbonates % CA	Matrix Carbonates % DO	Matrix Carbonates % TC	Matrix Carbonates C/D	Sand-Fraction Litho C/D	Sand-Fraction Litho TC	Sand-Fraction Litho SH	Sand-Fraction Litho TS	Sand-Fraction Litho TNS
		Westburg Paleosol																
26.9-27.3	(88.2-89.7)	Oe-Oab	Compressed, oxidized peat and peaty silt, spruce wood identified.															
27.3-28.0	(89.7-91.7)	Oe-MRL	(FCMP)	(locally, a mucky silt loam, or silt with organic fragments is preserved)														
28.0-28.4	(91.7-93.0)	Ab	(FCMP)	(samples below in parentheses, show broad, weathered, smectite peaks)														
		(28.1)					(56)	(23)	(21)									
		(28.3)					(50)	(15)	(35)									
28.4-29.9	(93.0-98.1)	Btgb	(FCMP)	(in poorly sorted, loamy sediments, with occasional pebbles)														
		(28.5)					(no illite apparent)											
		(28.7)					(78)	(10)	(18) (illite present?)									
		(28.9)					(64)	(12)	(24) (illite present?)									
		(29.1)					(no illite apparent)											
		(29.4)					(53)	(28)	(19)									
		(29.7)					(52)	(23)	(25)									
		(29.8)					(68)	(11)	(21) (illite present?)									
29.9-31.0	(98.1-101.7)	MRL	(FCm)	(crudely stratified loamy and silty sediments)														
		(30.0)					44	29	27									
		(30.5)		26.0	27.9	46.1	54	21	25					--	1	2	4	96
		(30.9)					39	30	31									
31.0-33.0	(101.7-108.2)	MOL	(SGm)	(sand and sand and gravel (Gmp))														
		(31.3)					(no illite)											
		(31.6)					(74)	(09)	(17) (illite present?)					--	6	--	8	92
		(32.5)					(no illite)											
		Undifferentiated Till																
33.0-33.1	(108.2-108.4)	UJL	(Dmm)															
		(33.0)		24.8	40.6	34.6	40	30	30									
33.1-34.7	(108.4-113.7)	UJU	(Dmm)															
		(33.1)		20.3	45.0	34.7	44	25	31	2.0	2.4	4.4	0.83	0.8	27	3	31	69
		(33.2)					42	28	30									
		(33.5)		19.2	45.2	35.6	38	26	36					--	22	6	30	70
		(34.1)		19.1	46.1	34.8	42	27	31	3.6	4.1	7.7	0.88	--	28	2	34	66
		Undifferentiated silts, with scattered organic-carbon																
34.7-35.6	(113.7-116.7)	UU	(Fm)															
		(34.9)		13.4	83.8	2.8	30	28	42									
		(35.2)		13.6	83.2	3.2	42	21	31									

Table 4. (Cont'd)

Depth		Horizon	Litho-		%			Clay Mineralogy %		Matrix Carbonates %				Sand-Fraction Litho				
m	(feet)	or zone	Facies	Clay	Silt	Sand	Ex.	Ill.	K + C	CA	DO	TC	C/D	C/D	TC	SH	TS	TNS
		Undifferentiated Till and Diamicton																
35.6-36.3	(116.7-119.0)	UJU	(Dmm)															
		(35.7)		20.1	39.8	40.1	39	21	40					0.1	15	2	21	79
		(36.0)		20.4	37.9	41.7	37	31	32									
							41	27	32					--	11	16	27	73
		(36.3)		17.5	29.1	53.4	38	26	36					--	12	3	28	72
36.3-36.5	(119.0-119.7)	MUU	(Dms)	(stratified diamicton; interbedded thin diamictons and sand partings)														
		(36.4)		16.5	26.4	57.0	44	23	33					--	7	4	20	80
36.5-36.6	(119.7-120.0)	OU	(reddish, iron-oxide cemented diamicton at contact with dolostone)															

DEVONIAN-
CEDAR VALLEY FORMATION

Laterally, the bedrock surface rises in elevation and the Alburnett Formation overlies greenish to bluish gray Pennsylvanian shale and mudstone. The lower 0.3m of the diamicton contains sheared inclusions of the Pennsylvanian rocks, and shows the following properties:

MUU (Dmm(s)) 37.9 39.6 22.5 38 33 29

Beneath this, the upper 0.2m of the Pennsylvanian mudstones are a sheared melange, with slicken sided surfaces. See text and figures.

Note: Clay mineralogy - Ex. = smectite; Ill. = illite; K + C = Kaolinite plus chlorite.

Matrix Carbonates - by modified chittick method; CA = % calcite; DO = % dolomite; TC = % total carbonate; C/D = CA/DO.

Sand Fraction Lithologies - C/D = calcite/dolostone ration; TC = % total carbonate; SH = % shale; TS = total sedimentary grains; TNS = % total non-sedimentary grains.

Table 5. Miscellaneous laboratory data from samples collected between 1974 and 1980.

Horizon or zone	% Clay	% Silt	% Sand	Clay Mineralogy % Ex.	Clay Mineralogy % Ill.	Clay Mineralogy % K + C	Matrix Carbonates % CA	Matrix Carbonates % DO	Matrix Carbonates % TC	Matrix Carbonates C/D	Sand-Fraction Litho C/D	Sand-Fraction Litho TC	Sand-Fraction Litho SH	Sand-Fraction Litho TS	Sand-Fraction Litho TNS
WOLF CREEK FORMATION															
Aurora-Hickory Hills? Till Member															
MRJU	22.1	38.2	39.7	61	18	21									
MOJU	20.1	35.5	44.4	67	15	18	1.0	1.4	2.4	0.71	7.5	17	--	17	83
MUJU	30.2	39.1	30.7	62	17	21	0.8	1.0	1.8	0.80					
Aurora Till Member (above intra-till contact)															
MRJU	25.0	38.8	36.2	58	18	24	4.1	6.9	11.0	0.59	0.65	43	--	43	57
MOJU	21.1	42.3	36.6	62	17	21	5.1	8.3	13.4	0.61	0.63	49	--	49	51
MRJU	21.7	45.0	33.3	63	17	20									
MUJU	32.2	40.0	27.8	66	18	16	1.0	0.4	1.4	2.5					
Aurora Till Member (below intra-till contact)															
MUJU	19.0	43.9	37.1	64	17	19	7.0	10.9	17.9	0.64	3.7	33	--	33	67
MUJU	20.2	39.9	39.9	58	18	24									
MUJU	21.1	38.5	40.4	66	16	18									
Winthrop Till Member															
MRJU	31.5	38.3	30.2	58	15	27									
MRJU	29.2	41.9	28.9	54	22	24	3.1	6.9	10.0	0.45	0.56	42	1	43	57
MUJU	24.7	38.8	36.5	60	14	26					1.0	44	4	50	50
MUJU	24.4	38.5	37.1	59	17	24	6.1	7.2	13.3	0.85					
ALBURNETT FORMATION															
Undifferentiated Till															
UJU	25.5	41.2	33.3	30	26	44	1.4	6.1	7.5	0.23	1.6	23	--	23	77
UJU	25.7	41.9	32.4	35	27	38	2.9	5.9	8.8	0.49	0.78	48	--	48	52
UJU	23.6	39.3	37.1	40	18	42	4.0	2.1	6.1	1.9					
UJU	23.8	38.1	38.1	32	25	43	2.3	5.5	7.8	0.42	--	18	4	23	77
UJU	19.0	33.9	47.1	39	23	38									
UJU				42	26	32									
UJU				37	29	34									
UJU				38	30	32									

Table 6. Summary of laboratory data for unweathered till samples from the Conklin Quarry.

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

Valley carbonates the diamicton tends to be massive (Dmm), but sometimes shows a pronounced horizontal fissility (or platy structure, Dmm(s)) which may result from shear stress and compaction in the subglacial environment. In places thin silt and sand "stringers" occur interbedded with the diamicton. These stratified diamictons and glaciofluvial deposits may result either from basal melt-out of diamictons and sorted debris or from block-inclusions and smudges of proglacial fluvial deposits incorporated into the basal till.

Where the lowermost diamicton unit overlies less-competent Pennsylvanian mudstones, shales and sandstones, is is comprised of two distinct increments. The lowermost increment is commonly a thin (0.3-0.5 m), complex diamicton unit dominated by sheared and deformed Pennsylvanian bedrock. Smears, smudges, and block inclusions are common throughout (Dmm(s) and Dms). The matrix clay-mineralogy consists only of illite, chlorite, and kaolinite, similar to the unaltered Pennsylvanian rocks. There is no smectite, and except for an occassional igneous cobble or pebble there is little erratic debris mixed in with this increment.

The lower increment grades upward into a more typical loam matrix (Dmm), mixed clay-mineralogy diamicton (upper increment) typical of the Alburnett Formation. The preponderance of 'shear' or at least deformation structures and substrate inclusions suggest that these diamictons are dominantly basal till. The thin, stratified diamictons (Dms) may represent melt-out till. Future fabric studies may aid in substantiating these more detailed interpretations.

Above the lower diamicton unit is a 2 to 8 m thick sequence of generally fining-upward fluvial and lacustrine deposits (figure 1). The base of the sequence is often comprised of a 'lag-gravel' grading upward into thin beds of sand with ripple-drift cross-lamination (Sr) and silts (Fl, Fsc, Fm).

In many places this stratified unit is angularly truncated by the overlying diamicton. However, in local swales on top of this fluvial sequence about one meter of lacustrine deposits, capped by a thin highly-compacted peat, are preserved (figure 1). These deposits are very fossiliferous and form the site of the Angerer local-biota discussed by Baker et al. (this volume). The paleontologic remains suggest that these deposits represent no more than an 'interstadial' break within the Alburnett sequence.

The uppermost Alburnett diamicton (till) unit ranges from about 2 to 8 m in thickness. Like the lowermost Alburnett diamicton, this unit also exhibits a thin basal increment with various shear structures and inclusions (Dmm(s)) which grades indiscernibly upward into a thicker, massive, uniform diamicton (Dmm). The lower, sheared increment ranges from about 0.2 to 1 m, and often exhibits a very pronounced fissile strucure. The underlying fluvial deposits are commonly deformed, exhibiting small, overturned folds and thrusts with axes trending N-NW to S-SE. Small block inclusions and smudges of the underlying fluvial and lacustrine deposits are common at the base of the increment, but decrease upward. This increment grades upward into a massive, dense (Table 8), uniform diamicton, or till. This upper increment is very uniform in composition, ranging only a few percent in matrix properties both vertically and laterally across hundreds of meters of exposure (Tables 3, 4, and 5).

The uppermost unit in the Alburnett Formation is a fining-upward fluvial sequence. The lowermost part of the sequence (2 to 5 m thick) grades upward from a thin, planar-bedded, clast-supported gravel (Gcp; locally containing large, telephone pole-size, spruce logs) into stratified sand (Sp). This is overlain by a 3 to 4 m thick, poorly sorted, weakly stratifed clay loam to silty clay loam with occasional pebbles (FC). This deposit is interpreted as colluvium and overbank alluvium. A poorly-drained, morphologically well-expressed paleosol is formed in these deposits. It exhibits strong B-horizon structure, continuous clay coatings, and an argillic horizon (see figure 2). (These features, however, may be influenced by the fining-upward nature of the deposit and later compaction by over-riding continental glaciers.) The degree of soil development observed in undeformed areas suggests that the unconformity represented by this paleosol is of 'interglacial' rank. This buried soil is overlain by the Winthrop Till Member of the Wolf Creek Formation and is correlated as the Westburg Paleosol (see Hallberg, 1980a, b). Locally the paleosol is deformed into massive sheared and slickensided blocks, obscuring the pedologic features.

A thin, compressed buried O-horizon (peat or mucky silty clay loam) fills small channels locally cut into the Westburg Paleosol (figure 1). Little pollen has been recovered from the peat, but spruce wood has been identified. This likely represents the return of a colder, glacial, climate during advance of the ice that deposited the overlying Winthrop Till Member of the Wolf Creek Formation.

Wolf Creek Formation

The Wolf Creek Formation is the youngest Pre-Illinoian formation in Iowa. It is differentiated from the Alburnett Formation on the basis of higher percentage of expandable clay minerals (mean of 61% vs. 43%; Table 1). Where the whole sequence is preserved, the Wolf Creek Formation consists of three till members, from oldest to youngest, the Winthrop Till Member, the Aurora Till Member, and the Hickory Hills Till Member. These till members are differentiated on the basis of various laboratory-derived data (Hallberg, 1980; Hallberg et al., 1980b). The Winthrop and Aurora Till Members are well exposed at Conklin Quarry. The Hickory Hills Till Member may be present, but intense pedogenic alterations associated with the Late-Sangamon Paleosol make its recognition problematic.

Winthrop Till Member

The Conklin Quarry excavation has provided one of the few persistent exposures of the Winthrop Till Member in eastern Iowa. This unit has varied from 5 to 10 m in thickness. At the base of the diamicton (till) are a variety of shear, low-angle thrust, and deformation structures (Dmm(s)) similar to those described at the base of the upper-Alburnett diamicton. The lower portion of the diamicton also contains abundant, block-inclusions, smears, and smudges of substrate materials, such as peat, wood, paleosol, and Pennsylvanian mudstone. Such inclusions occur throughout the Winthrop Till Member, but become much less common going upward in the section. Above the basal zone, the Winthrop Till Member tends to be a massive diamicton (except for secondary, vertical joints) and uniform in its matrix properties (Table 6). At Conklin Quarry it

Table 7. Summary of particle-size data for till members of the Wolf Creek Formation in eastern Iowa (data from Hallberg, 1980a,b).

	Particle Size - %		
	Clay Mean s.d.	Silt Mean s.d.	Sand Mean s.d.
		Hickory Hills Till Member	
N = 283	22 ± 4	34 ± 4	44 ± 4
		Aurora Till Member	
N = 197	22 ± 4	40 ± 4	38 ± 5
		Winthrop Till Member	
N = 60	26 ± 4.0	41 ± 4	33 ± 4

has slightly lower clay content (Table 7) and exhibits the same diagnostic relationship between texture and carbonate content (Tables 4 and 5) as noted regionally (Kemmis and Hallberg, 1980). The Winthrop Till Member at Conklin Quarry is interpreted as a basal till on the basis of sedimentary strucutres, the generally uniform matrix properties (except the block inclusions, etc.) and density.

The upper surface of the Winthrop Till Member is truncated. At present there is generally a till-till contact with the overlying Aurora Till Member. This contact is marked by various features, including abrupt changes in color and matrix properties, thin stringers of sorted debris (sands or silts), and aligned logs and pebbles. A cross-section of a deformed fluvial channel fill capped by peat occurs on the west overburden wall (this is poorly exposed and largely overgrown today). This appears to be a lateral equivalent of a fluvial sequence surmounted by the Franklin Paleosol which was well exposed in 1975-76 (figure 1). At that time, swales on the Winthrop Till Member surface were filled with a fining-upward sequence of fluvial deposits (S-F) generally composed of planar-bedded sand, grading upward to interbedded fine sands and silts. These were generally capped by (0.3 to 1.0 m) massive silt loam to silty clay loam. A weakly expressed buried soil was present in the top of this unit. Locally, a compressed peat or muck (O-horizon) capped the paleosolum. This paleosol was a weakly developed example of the Franklin Paleosol (Hallberg, 1980b). It has varied in expression from an O-Ab-C or Ab-C soil profile to a O-A-Bwgb profile. When best expressed (see figure 1; Table 4) the paleosol profile exhibited a gleyed, cambic B-horizon (Bwg with weak to moderate pedogenic structure). Pollen analysis of the peat capping the Franklin Paleosol showed very little well-preserved pollen. A few spruce, chenopod, and grass pollen grains were identified, as was spruce wood. It would appear that the weakly expressed Franklin Paleosol and underlying fluvial deposits mark an interstadial level unconformity in the glacial sequence at this location.

Aurora Till Member

The Aurora Till Member overlies the Winthrop Till Member and the Franklin Paleosol (figure 1). The thickness of the member has varied from about 6 to 12 m. As with the previously described units, the lowermost portion of the Aurora diamicton shows various shear and deformation structures and contains common block inclusions and smudges of local substrate materials. The matrix properties of the Aurora diamicton (Table 6) are similar to region-wide averages (Table 7), although at Conklin the unit tends to be slightly higher in percent clay and lower in sand content. There is also the same relationship between texture and carbonate chemistry that is present regionally (see Tables 4 and 5; Kemmis and Hallberg, 1980).

A discontinuity occurs within the Aurora Till Member at Conklin Quarry approximately 1 to 3 m above the base. This discontinuity is expressed as a discontinuous zone of water seepage and minor color (weathering zone) changes in the diamicton. This zone is comprised of a composite of features: 1) thin (0.03 -0.3 m), elongate (0.1 -1.54 m) sand and/or gravel stringers; 2) prominent, thin fissile partings in the diamicton around these lenses; and 3) occasionally a 'till-till' contact between the lenses marked by abrupt (albeit subtle) color changes. Only very minor changes in matrix properties occur across the discontinuity (see Tables 3-6; figure 2). This zone is interpreted as an intra-Aurora Till Member contact (IAC on figure 1) between basal tills. This discontinuity is not considered to represent any major temporal unconformity in the sequence. It may simply represent a change in subglacial deposition or an interstadial break; i.e., it may represent a minor retreat and the readvance of ice. Fabric studies in progress may clarify the relationship between these units.

Hallberg (1980a, b) has previously noted that various Pre-Illinoian till members (such as the Aurora) are locally comprised of multiple diamictons with similar properties, but there is no evidence to suggest that these represent major unconformities (a major paleosol, etc.) of interglacial nature. The multiple till-depositional units of the Aurora Till Member or Alburnett Formation may simply represent multiple advances and retreats of continental ice sheets during a single glacial 'stage,' analogous to the multiple tills deposited during the Wisconsinan.

Hickory Hills or Aurora Till Member

Presently the Hickory Hills Till Member is poorly exposed at Conklin Quarry. During 1975-76 thicker portions of the upper Wolf Creek Formation were exposed (figure 1; Table 4). At that time, the typical sequence of gradational weathering zone changes was encountered below the Late-Sangamon Paleosol (MOJL grading downward to MRJU to MR-UJU diamicton). Sand bodies occurred in the lowermost weathering zone. Around the sand bodies color-related weathering zones became very complex, related to variable secondary oxidation. Between sand bodies there was a 'till-till' contact marked by an abrupt color (weathering zone) change (MUJU diamicton above and MR-MOJU diamicton below) and an abrupt textural change. The diamicton above the contact was relatively sandy, averaging 43% sand, 34% silt; while the diamicton below averaged 34% sand and 42% silt (Table 6). These textural changes are typical of regional changes between the Hickory Hills Till Member and the subjacent Aurora Till

Table 8. Bulk-density data for till units at Conklin Quarry.

N	Mean density g/cc	Range, g/cc
WOLF CREEK FORMATION		
Hickory Hills or Aurora Till Member		
11	1.82	1.76 - 1.88
Aurora Till Member		
10	1.83	1.80 - 1.98
Winthrop Till Member		
4	1.96	1.89 - 1.98
ALBURNETT FORMATION Till, undifferentiated		
9	2.04	1.97 - 2.11

Member (Table 7). Regionally these tills are separated by a variety of deposits and a major buried soil, the Dysart Paleosol, although locally these deposits and paleosol have been erosionally truncated (Hallberg, 1980a, b).

Various features were associated with the sand bodies. Some were marked by flat upper surfaces overlain by 0.1 - 0.3 m of platy, fissile diamicton (Dmm(s)?). In other places, diffuse bedding in the sand bodies appeared to be deformed and overturned. However, some irregular-shaped sand bodies at the 'till-till' contact had no evidence of deformation.

These various observations do not lead to an unequivocal interpretation. Three alternative hypotheses can be made: 1) The upper diamicton represents the Hickory Hills Till Member, and the sand bodies are various proglacial, subglacial or interstadial fluvial deposits which were, in part, deformed by overriding ice; 2) The upper diamicton represents another basal till unit of the Aurora Till Member, with a similar complex origin for the sand bodies; and 3) The sand bodies, and upper (relatively) sandy diamicton, represent a supraglacial facies of the Aurora Till Member.

The first alternative is the favored hypothesis for several reasons: 1) the textural data suggest a correlation with the Hickory Hills Till Member; 2) the weathering zone changes at the abrupt 'till-till' contact observed in 1975-76 suggest a major break in the stratigraphy (similar to the Aurora-Winthrop contact); 3) the nature of most of the sedimentary structures suggest that these are both basal tills (in the generic sense); 4) the density and consolidation characteristics of the upper diamicton (Table 8) also suggest that it is a basal till (see Kemmis et al., 1981; Lutenegger et al., 1983); 5) The upper diamicton unit, unfortunately, has always been relatively thin, and weathering alterations (e.g., leaching, oxidation) have often extended nearly throughout the unit; the few samples that could be analyzed for carbonate chemistry (that were not affected by these alteratons) also suggested correlation with the Hickory Hills Til Member; and 6) in higher elevation primary divide areas nearby, the Hickory Hills Till Member occurs as the youngest Pre-Illinoian glacial deposit (Hallberg, 1980a). All these criteria, except the textural and carabonate data, could be compatible with alternative 2 as well, and the unit is labeled as either Hickory Hills or Aurora on the various tables and figures. The third hypothesis is not compatible with the evidence. The sand bodies are enclosed in otherwise massive diamictons. There have been no structures apparent to suggest supraglacial deposition (see Boulton, 1971, 1972; Lawson, 1979, 1982).

No fabric studies or more detailed sampling was done while the unit was best exposed. The only remnant of the Hickory Hills Till Member that may remain is a thin (about 1 to 1.5 m) unit of relatively sandy diamicton (see bottom of Table 3) that occurs above the general level of the sand bodies in the crest of the Late-Sangamon paleohillslope (figure 1). The weathering associated with the Late-Sangamon Paleosol extends through the entire unit obscuring most primary features.

Till Joints and Other Secondary Features

The Conklin Quarry exposure is an excellent place to observe secondary, vertical joints that commonly occur in the dense, highly consolidated Pre-Illinoian basal tills in Iowa. Their presence has been noted in preceding discussions and descriptions. The joints extend downward from large prismatic structural units within the Late-Sangamon Paleosol (LSP). The most prominent and vertically persistent joints form polygonal patterns about one meter in diameter, and likely originated as dessication features as the water-table was lowered in response to the evolution of the drainage network.

The joints are vertically persistent between till units, passing through 'till-till' contacts from one till to the next in the Wolf Creek sequence. However, intensity of the jointing decreases with depth. Joints are not as prominent (or are absent) in much of the Alburnett sequence because the Alburnett diamictons (the UU zones) remain saturated, as shown by unoxidized weathering zone colors and perennial, slow seepage of water from parts of the Alburnett Formation.

The orientation of the joints is not random. They show preferred orientations both locally and regionally, which may be related to long-term stress fields. Future research will look at the nature and (hopefully) origin of the joints.

The joints form avenues for water and air movement and the translocation of materials through the otherwise dense and low permeability till sequence. This is why the joints are so prominent: they show marked color (oxidation related) weathering zone contrasts between the joint area and the surrounding matrix. In higher portions of the section, a variety of secondary deposits occurs within the joints: 1) clay and silt coatings; 2) iron and manganese oxide cements; and 3) calcium carbonate cements. In the zone of secondary carbonate deposition (2 to 4 m below the top of the LSP) many secondary carbonate features occur including: 1) vertical cemented zones in some joints; 2) carbonate-cemented sand-bodies; 3) a variety of nodules and concretions; 4) carbonate pendants on pebbles and in voids; and 5) other geopetal structures.

Late-Sangamon Erosion Surfaces and Paleosols

The uppermost Pre-Illinoian deposits have been truncated by the Late-Sangamon erosion surface (LSES, figure 1). The erosion surface is marked by a stone-line which occurs within the Late-Sangamon Paleosol (LSP). Above the stone-line the LSP is formed in Late-Sangamon pedisediment (LSPs), a hillslope deposit derived from erosion upslope and transported part way down the pediment or erosion surface (see Canfield et al., in press, for further discussion). The LS paleolandsurface was exposed for a long time (the time of development of the LSP) before burial by Wisconsinan loess. From a distance the most prominent feature of the Quaternary sequence at Conklin Quarry is the Late-Sangamon Paleosol (LSP), developed in the top of the Pre-Illinoian sequence. Its generally dark-reddish brown color marks an arcing band across the section. A description of a typical LSP occurring on the crest of the LS paleohillslope (as at A in figure 1) is given in Table 9, while particle-size data are shown in figure 3-A. The LSP in such a position is a morphologically well-developed soil. It exhibits an E-horizon (Guthrie and Witty, 1982) and a well-developed, reddish-brown argillic B-horizon (note clay "bulge" in figure 3-A).

Through time, quarry operations have exposed different portions of the LS paleohillslope. Locally the LS surface descends to shallow swales, former drainageways or sidevalleys on the LS surface (see also Ruhe et al., 1967). In such positions, the LSPs thickens into the swale. Here the LSP no longer exhibits dark-reddish brown color, but is gleyed, marked by mottled, gray and greenish colors indicative of the poor soil drainage in this landscape position.

During 1975 and 76 a large and deep LS sidevalley or gully was exposed (see location B on figure 1; stratigraphy and particle-size data shown on figure 4). The base of the gully was marked by a thick cobble lag (LSES stone-line equivalent). The gully was nearly 6 m deep and about 3 m wide. The alluvium filling the gully was comprised of poorly-sorted and crudely-stratified deposits grading upward from sandy loam to silty clay loam, clay loam, and clay at the top of the section. Occasional pebbles and cobbles occurred throughout the deposit. A gleyed, poorly-drained, but still strongly-developed soil was present in the top of this LS alluvium, continuous with the better-drained LSP on the pediment (figure 1). There was evidence of multiple soils developed within the alluvial fill, marked by horizons enriched in organic matter (Agb) and structural B-horizons (Bwgb).

Between 20-25,000 RCYBP the LS paleosurface was buried by a thin increment of basal loess sediments (BLS). A weakly-developed soil (BLP) formed in this loess and the upper part of the subjacent LSP (see Canfield, et al., in press, for further discussion).

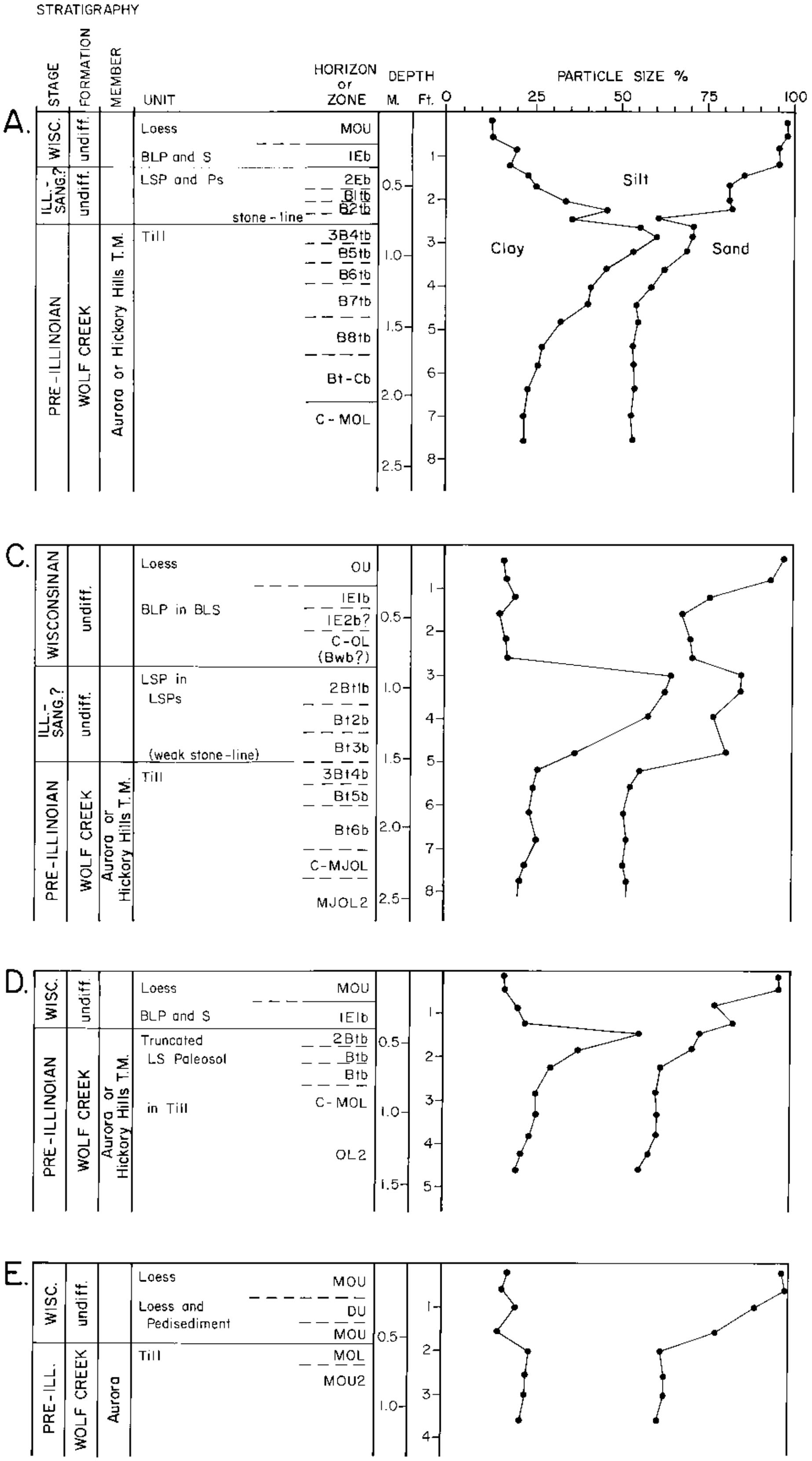

Figure 3. Stratigraphy and particle-size data for various settings (A-E, shown on figure 1) on the LS paleolandsurface at Conklin Quarry.

Table 9. Description of Late-Sangamon Paleosol on crest of paleo-interfluve at Conklin Quarry; Site A; Figures 1 and 3 (description by T. Bicki, S. Esling, and G. Hallberg).

Depth m	Horizon or Zone	Description
WISCONSINAN Wisconsinan loess		
0-0.25	MOU	Mottled yellowish brown (10YR5/4) silt loam; common fine mottles; massive; clear, smooth lower boundary; few snail shells.
Basal-loess paleosol Basal-loess sediments		
0.25-0.37	1Eb	Brown (10YR5-4/3) silt loam (more sand than above); common faint yellowish brown (10YR5/4-6) mottles, few fine light gray (10YR7/1) grainy silt coats (silans); weak thin platy, breaking to weak very fine subangular blocky; common fine root tubules; friable; few fine charcoal flecks; clear smooth lower boundary.
Late? SANGAMON Late-SANGAMON PALESOL Late-Sangamon Pedisediment		
0.37-0.50	2Eb	Mixed reddish yellow (7.5YR6-5/6) to yellowish brown (10YR6-5/6) loam; moderate thin platy breaking to moderate very fine subangular blocky; common moderate silt coats (as above), common, thin strong brown (7.5YR4-5/6) coatings on plates and tubules; few thin, discontinuous clay films; very friable; few fine charcoal flecks; clear, smooth lower boundary.
0.50-0.59	2Bt1b	Strong brown (7.5YR5/6) clay loam; common fine dark brown (7.5YR4-4/6) mottles and coatings; moderate fine subangular blocky; thin to medium discontinuous clay films, few fine silt coats; firm; few fine charcoal flecks; gradual lower boundary.
0.59-0.70	2Bt2b	Dark brown (7.5YR4/4) clay; common fine strong brown (7.5YR5/6), yellowish red (5YR5/6), and yellowish brown (10YR5/4-6) mottles; strong fine subangular blocky; thin nearly continuous clay films, continuous moderate films on vertical tubules; few light gray (10YR7/1) and yellowish brown (10YR5/6) silt coats; firm; few charcoal flecks; gradual lower boundary.
0.70-0.76	Bt3b	Stoneline (gravelly clay loam) at contact between units.
Late-SANGAMON Paleosol PRE-ILLINOIAN Wolf Creek Formation Aurora (or Hickory Hills) Till Member		
0.76-0.89	3Bt4b	Mottled dark brown (7.5YR4/4), strong brown (7.5YR5/6), yellowish red (5YR4/6), dark yellowish brown (10YR4/4) clay with some pebbles, few fine red (2.5YR4/6 and 3/6) mottles; very strong, fine subangular to angular blocky structure; continuous moderate, common thick clay films; very firm; gradual lower boundary.

Table 9 con't.

0.89-1.11	3Bt5b	As above; with few, medium, dark gray and gray mottles and coatings; slickensided pressure faces on thick clay coatings along vertical cleavage planes; abrupt lower boundary.
1.11-1.18	3Bt6b	Dark yellowish brown (10YR4 and 5/4) and light olive brown (2.5Y5 and 4/4) heavy clay loam with some pebbles; common fine and medium strong brown (7.5YR4/6 and 5/6-8) and few medium yellowish red (5YR4/6) mottles ; strong medium and fine subangular to angular blocky structure; nearly continuous moderate clay films; some peds with bare interiors; firm; common pressure faces on vertical cleavage planes; gradual lower bounday.
1.18-1.40	3Bt7b	Light olive brown (2.5Y5/4) clay loam with some pebbles; common brown and red mottles as above; strong, medium, subangular blocky, breaking to moderate, fine subangular blocky; nearly continuous thin clay films on medium peds, common thin coatings on fine peds; firm; clear, wavy, lower boundary.
1.40-1.69	3Bt8b	Yellowish-brown (10YR5/6) clay loam with some pebbles; common strong brown (7.5YR5/6) mottles and coatings, common, coarse, thick, very dark gray (5YR3/1) manganese oxide and clay coatings on larger structural units; strong medium, breaking to weak fine subangular blocky structure; common thin clay films; clear, wavy lower boundary.
1.69-2.04	3Bt-Cb	Yellowish-brown (10YR5/6) heavy loam with pebbles; common manganese oxide coatings as above; moderate medium to coarse subangular blocky; common thin clay films; diffuse, irregular boundary.
2.04-2.50	3C-MOJL	Dark yellowish brown (10YR4/4) loam with pebbles; common yellowish brown (10YR5/6-8), brown (10YR4/4), strong brown (7.5YR4-5/6), and pale olive (5Y6/4) mottles; moderate coarse angular blocky to massive; firm; few manganese oxide and clay coatings, brown mottles along vertical joints.

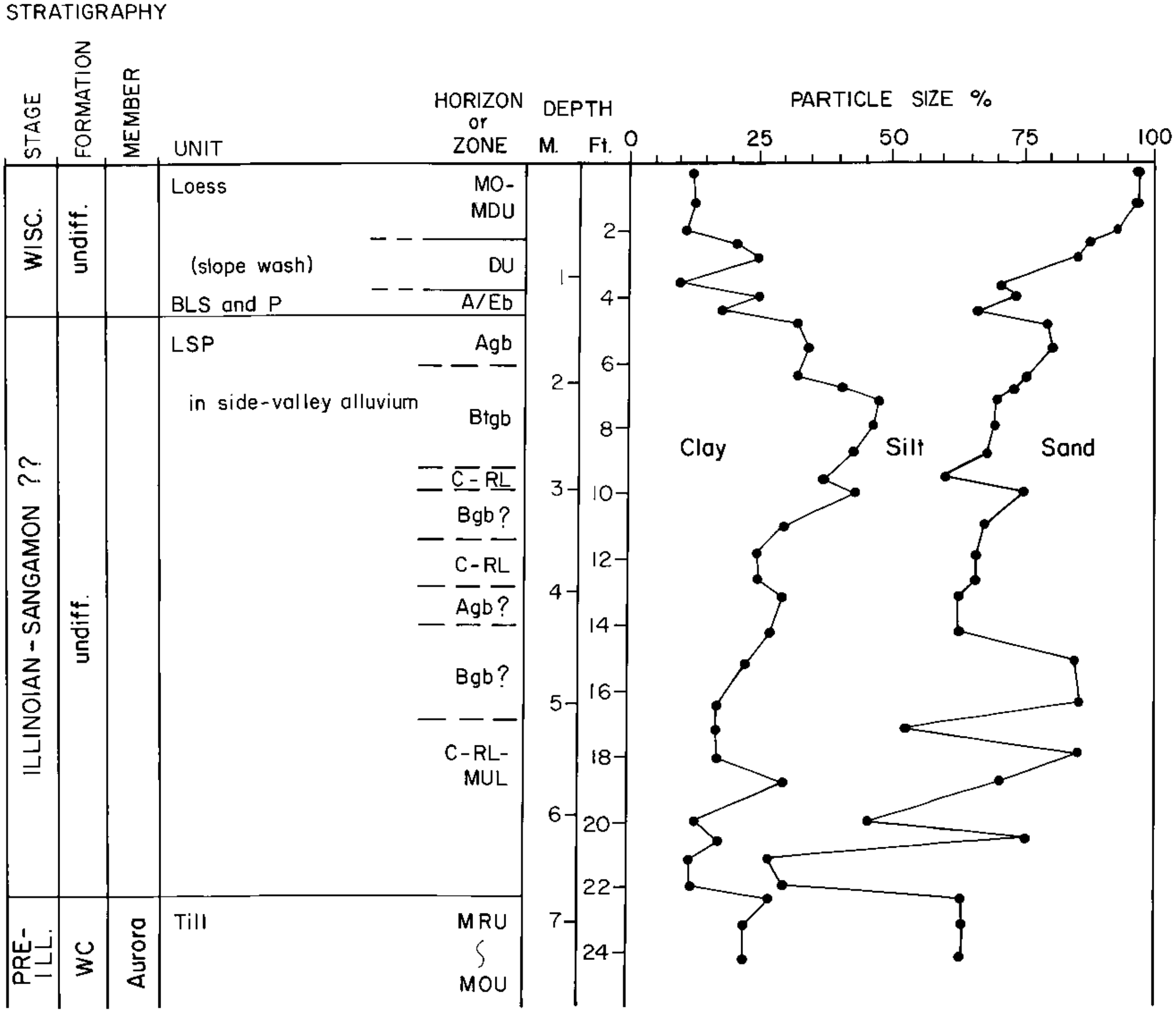

Figure 4. Stratigraphy and particle-size data for LS side-valley alluvium; shown at B on figure 1.

Wisconsinan Erosion Surfaces

On sloping portions of the LS surface younger "gullies" or erosional channels are obvious (figure 1). In some areas the LSP is gullied--truncated by erosion. The gullies are then filled with a thicker increment of BLS (as shown in C on figures 1 and 3). In these settings the BLS and BLP overlay a truncated B-horizon in the LSP; note the abrupt clay increase in Figure 3-C at the discontinuity between the BLS-BLP and LSPs-LSP. The discontinuity is even more striking on steep paleo-sideslopes (such as D on figures 1 and 3) where the LSP is severely truncated by erosion (LSPT), and the BLS-BLP lay unconformably on a very thin, yet still well-expressed remnant of the LSP. These erosional events took place during the Wisconsinan prior to ca. 25,000 RCYBP (i.e. -the age of the BLP).

Overlying the LS sidevalleys, stratified slopewash deposits often occur in the base of the loess (yet above the BLS-BLP). This is the stratigraphic setting of the Conklin local biota (see Baker et al., this volume) where wood from the strata was radiocarbon dated at 17,010 RCYBP (figure 1).

Later Wisconsinan erosion surfaces have also been exposed in the quarry. In 1975-76 the quarry operations cut through a Wisconsinan "Iowan" erosion surface (Iowan ES, figure 1). Here, the BLS, BLP, LSES, and LSP were truncated on a steep paleo-backslope (LSPT near D on figure 1). The erosion surface flattened out onto a pediment marking the IES. The stratigraphy and particle-size data of a typical section on the pediment (as at E, figure 1) is shown on figure 3-E. The eroded till is directly overlain by calcareous Wisconsinan loess and slope-wash (pedisediment). The base of the loess in such settings typically dates about 17,000 RCYBP (Hallberg et al., 1978c). The described portion of this paleolandscape is now buried under the berm along the west side of the quarry. Smaller scale, analogous features can be seen in paleo-gullies on the east side of the present exposure.

These various erosional and depositional events (the deep entrenchment shown by the LS side-valley, and the Wisconsinan gullies and erosion surfaces) are the upland responses to a complex history of downcutting and aggradation by the adjacent Iowa River.

Wisconsinan Loess

Wisconsinan Loess is the uppermost deposit at Conklin Quarry. This silty, windblown deposit originated from the adjacent Iowa River valley between about 25,000 and 14,000 RCYBP (Hallberg et al., 1978; Lutenegger, 1979), and buried the entire Late-Wisconsinan landscape. At Conklin Quarry the loess is approximately 20 feet thick on the hillslope crest and thins to about 8 feet on the IES (figure 1). The loess contains five weathering zones from bottom to top: 1) a basal deoxidized leached zone (DL2); 2) a deoxidized and unleached zone (DU); 3) a mottled, oxidized, and unleached zone (MOU); 4) an oxidized and unleached zone (OU); and 5) an oxidized and leached zone (OL). Snail shells are common in the unleached portions of the loess. Numerous secondary concretions such as pipestems (vertically elongate iron concretions), carbonate concretions (loess kindchen) and mottles are present. These are related to post-depositional alterations associated with weathering and soil development in the loess.

PARTING THOUGHTS

The Conklin Quarry provides an important view on some of the problems which frequently occur in the study of older, Pre-Wisconsinan deposits in the Midwest. First, the deposits are often significantly weathered. As a consequence, standard sedimentologic study to determine the origin of the deposits becomes much more difficult, particularly when compared to the study of younger, less modified glacial deposits. For example, oxidation and leaching of the likely Hickory Hills Till Member precluded certain analyses (particularly matrix carbonate analyses) which have proven useful for correlation and characterization. Leaching and oxidation can also affect pebble fabrics (see Canfield et al., in press) and paleomagnetic determinations (see Baker and Stewart, this volume).

Another problem is the relationship between landscape evolution and the stratigraphy. Development of LSES beveled and esssentially removed all traces of the Hickory Hills Till Member (figure 1). Also, the IES remnant formerly exposed in the quarry cut below the Hickory Hills Tills Member, and the 'surface till' in this landscape position was the lower portion of the Aurora Till Member. The steep paleoslope on the east side of the quarry at times has even cut down into the Winthrop Till Member. When working with isolated outcrops or even drill cores on different landscape positions, workers must be cognizant of these geomorphic-stratigraphic relationships. However, the relationship between the landscape and the stratigraphy is no different than in any other area of dissected, relatively flat-lying sedimentary rocks. As the landscape declines in elevation from primary to secondary divides or down stepped pediment surfaces locally, younger stratigraphic units are truncated by erosion, exhuming older units at the landsurface (see Hallberg, 1980a).

Another related problem in studying these older Pleistocene sequences is that the record at any one section may be far less complete than at Conklin Quarry. For example, at Klein Quarry (figure 5) just a few kilometers to the southwest, only two thin diamicton or till units are present. How are these related to the multiple tills exposed at Conklin? The stratigraphic sequence is less complete because the rock units have been subject to subsequent glacial erosion during later glaciations or to subaerial erosion during any of the various interglacial or interstadial episodes. These problems point out the need for the use of secondary data (e.g., texture, clay and carbonate mineralogy) to characterize and correlate between sites.

An even greater problem for correlation is the age or time-stratigraphic placement of these Quaternary rocks. In western Iowa, radiometric dating of volcanic ashes within the till sequence indicates that the Pre-Illinoian glacial deposits range in age from somewhat younger than 600,000 ybp to older than 2 million ybp (Boellstorff, 1978a, b; Hallberg and Boellstorff, 1978; Hallberg, 1980c). No ashes have been found in eastern Iowa. The great complexity now demonstrated within the Quaternary sequence (see Hallberg, 1980 a, c; Hallberg and Boellstorff, 1978) indicates that the classical stage definitions (Kansan, Aftonian, Nebraskan) are no longer valid. These deposits are now simply referred to as Pre-Illinoian, undifferentiated, until the rock-stratigraphic sequence is known in more detail. Rock stratigraphy is of far more importance to understanding the geologic sequence and for use in applied problems. Time stratigraphy is a luxury which affords geologists much recreation making long-distance correlations.

To address the time-stratigraphic problems in eastern Iowa, research into paleomagnetic remanence and polarity has been initiated (Baker and Stewart, this volume). They outline some preliminary results indicating that the Alburnett Formation deposits exhibit reversed polarity. This suggests that these deposits are older than about 730,000 ybp. Continuing work is being undertaken to substantiate these results in more detail. A variety of research will continue at the Conklin Quarry, which hopefully will provide more insights into the Quaternary history of Iowa.

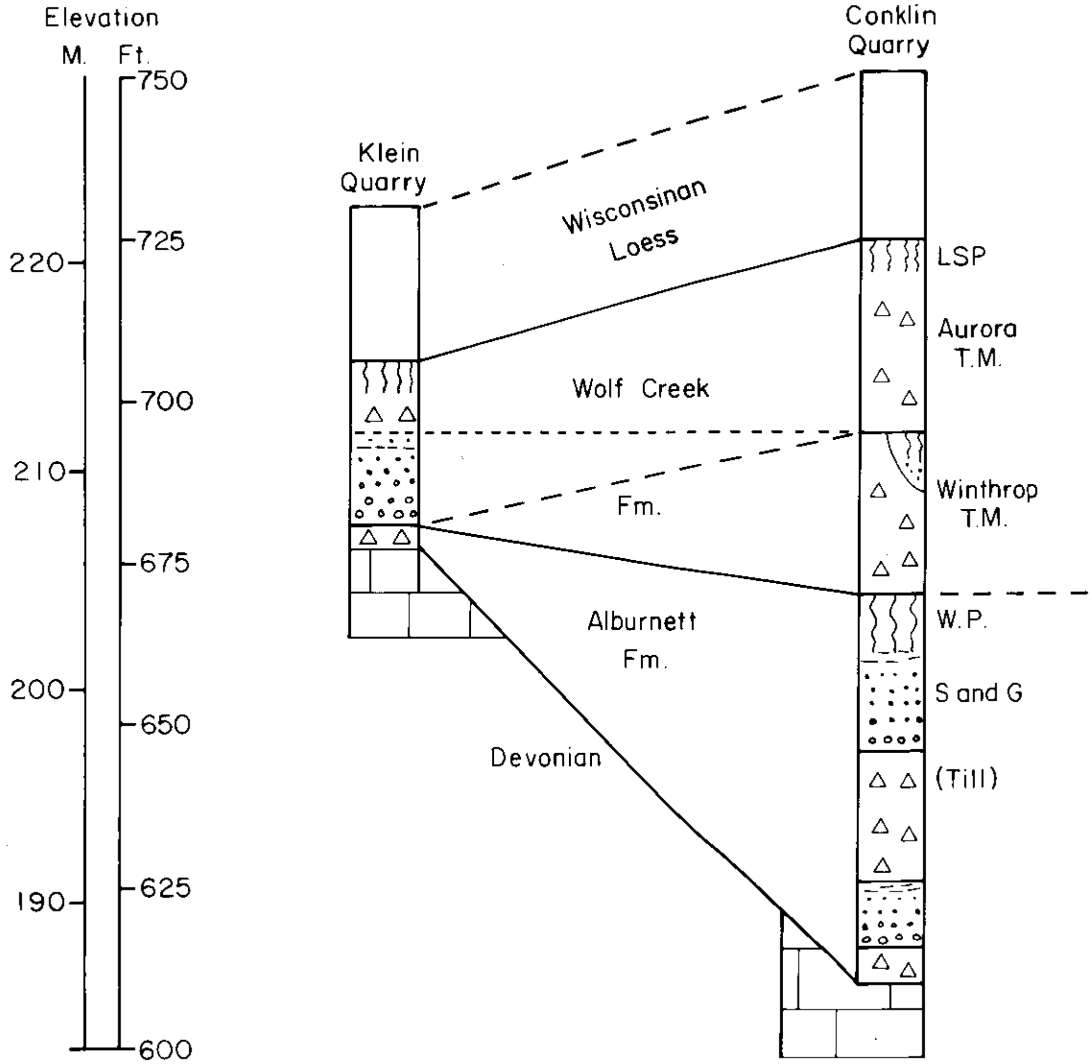

Figure 5. Correlation of Quaternary sections between the Conklin and Klein Quarries in the Iowa City area.

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PALEOMAGNETIC STUDY OF GLACIAL DEPOSITS AT CONKLIN QUARRY AND OTHER LOCATIONS IN SOUTHEAST IOWA

Joseph L. Baker
Robert A. Stewart

Department of Earth Sciences
Iowa State University
Ames, Iowa 50010

Paleomagnetic study of glacial sediments in southeast Iowa is currently in progress, with emphasis on Illinoian and Pre-Illinoian tills. A major focus of our efforts is Conklin Quarry in Iowa City because of the excellent exposures of Pre-Illinioan glacial deposits. We present here the results of our initial phase of sampling.

Samples were obtained by two methods: Firstly, 1 cm^3 plastic boxes were oriented and pressed into leveled surfaces, and secondly, oriented blocks of till were removed from the same exposure. Later these blocks were sampled using a 1" diameter diamond drill bit. The latter procedure yielded the best results, as the dried sediments did not deform during drilling as did the till and silt at the edges of the boxes during insertion. All samples were analyzed at the University of Minnesota. Selected data are presented in Table 1.

The most interesting aspect of the study to date is the recognition of a magnetic reversal in the Alburnett Formation exposed at Conklin Quarry (figures 1 and 2). Sample declinations range from 119° to 183° and inclinations from -14° to -49°, relative to the present day field of about 0° declination and 62° inclination (cf. Glassford Fm. figure 1). Additional sampling will hopefully strengthen the results. This reversal could potentially provide a valuable correlation tool during analysis of Pre-Illinoian tills in Iowa and elsewhere (cf. Baker et al., 1983).

The Winthrop Till Member of the Wolf Creek Formation shows normal polarity based on eleven samples. This unit will be sampled further in the future. A strongly-developed platy structure in the Aurora Till Member has so far defeated sampling by either cubes or blocks, but attempts will be made again, also at a future date.

The Hickory Hills Till Member and Illinoian Kellerville Till Member were sampled extensively at the Pleasant Grove site in Des Moines County, Iowa (Hallberg et al., 1980, p. 24). Both till units exhibited normal polarities with varying degrees of statistical confidence (figures 1 and 2). On the basis of their colors (yellow-brown) and erratic demagnetization results of pilot samples, the tills' (and those older, as well) magnetic signatures are apparently overprinted by a secondary magnetic component (probably hematite) related to weathering (which we have elaborately rediscovered). The mineralogy will be determined more precisely by inducing an isothermal remanent magnetism to the sample. Different magnetic minerals (e.g. magnetite vs. hematite) will show contrasting saturation magnetization levels. Future sampling of the Kellerville and possibly the Hickory Hills Members will concentrate on the Nelson Quarry site (Hallberg et al, 1980, p. 50) to examine inter-site variability.

Future Considerations Regarding Paleomagnetic Analysis and Till Genesis

The magnetization of glacial sediments (or any sediment in general) upon deposition is termed the detritral remanent magnetization (DRM). The DRM is commonly overprinted by secondary magnetic components (hematite and goethite related to weathering effects). As discussed above, stepwise demagnetization can disclose a primary remanence field strength and direction which, when applied to a sample, most clearly shows the DRM signal. This procedure requires examination of many samples for consistent trends in demagnetization, which will be pursued in the future.

DRM is established as small magnetic particles settle in a fluid (lake water, sediment pore water, etc.) during deposition. This primary DRM may be significantly disturbed if particles 10 - 180 μm in diameter or larger are affected by external forces such as viscous flow or shear. For silt-sized particles the critical limit is in the range 40-50 μm (Tarling, 1983). Thus, only particles smaller than these critical size ranges are likely to retain a stable DRM. Certain subglacial tills (lodgement till, deformation till: Dreimanis, 1976) are deposited under the influence of strongly directed glacial shearing stresses, which causes the physical alignment of larger (magnetic) grains (Boulton, 1976). This effect bears on our study in that the magnetization of the tills may comprise detrital remanence *sensu stricto* (fine particles) and a magnetic "fabric" developed in coarser particles from subglacial stresses. In-as-much as tills of the Wolf Creek and Alburnett Formations are likely of subglacial origin (possibly lodgement), based on cursory field investigations, the latter phenomenon is of prime importance to correctly interpret the paleomagnetic record of these tills.

A solution to this problem may be found through the study of the anisotropy of magnetic susceptibility (AMS) of the tills. The use of AMS will potentially discriminate between the "true" DRM and any glacially-induced orientation of larger magnetic grains. Isotropic magnetic susceptibility (IMS) is a simple, related technique which quantifies the abundance of magnetic minerals in a given sample (Chernicoff, 1980). Its use has broad applicability for fingerprinting and correlating tills of varying antiquity over large areas.

Table 1: Selected paleomagnetic data for glacial sediments at Conklin Quarry and elsewhere in southeast Iowa

		Mean remanence direction			
	N	Declination (degrees)	Inclination (degrees)	K	α 95 (degrees)
Glasford Fm:					
Kellerville Till Mbr.					
Supraglacial Facies	Pilot	358.64	61.41		
" "	4	321.64	45.45	8.77	32.89
Subglacial Facies	12	354.70	42.11	5.62	21.17
Wolf Creek Fm:					
Hickory Hills Till Mbr.	16	359.27	45.53	2.25	31.54
" "	11	7.09	53.28	2.80	36.65
Aurora Till Mbr.	6	54.94	33.49	1.15	?
Winthrop Till Mbr.	4	325.93	47.93	9.06	31.31
Alburnett Fm:					
Till	8	119.56	-35.49	4.38	32.62
Till	5	184.29	-18.01	7.99	28.84
Silt	Pilot	175.36	-49.17		
Silt	5	138.37	-33.40	91.24	8.05
Silt	5	185.99	-14.50	11.46	23.60

α 95= Angular radius of a cone of confidence K= Precision Parameter (Fisher, 1953)

Acknowlegements

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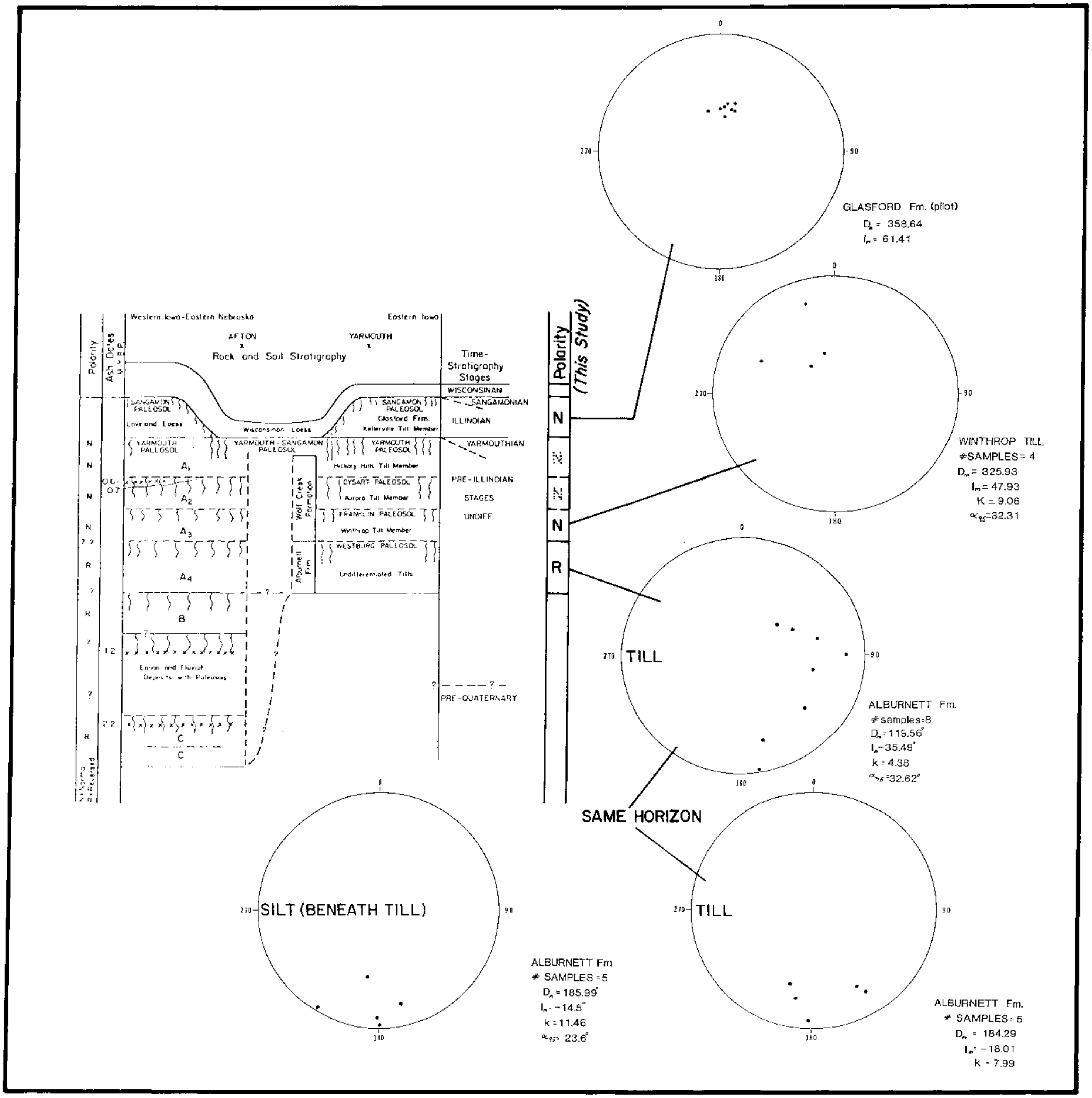
Figure 1. Schematic diagram of stratigraphy and tentative correlations of glacial deposits across the region eastern Nebraska - western Iowa - eastern Iowa (after Hallberg, ms.), showing geopolarity data for the latter region. Illinoian till (Kellerville Member of Glasford Fm.) as well as the Hickory Hills Mbr. were sampled near Danville*, Iowa; other data are for Pre-Illinoian glacial deposits occurring at Conklin Quarry. Based on these and other data obtained to date, we confidently assign normal (N) or reversed (R) polarity to the units shown on the right side of the diagram. The reversed polarity of the Alburnett Fm. is manifested in till and glaciolacustrine (?) silt. Sampling problems (fracturing and clast content), scant data and possible secondary magnetic overprinting preclude more than a hesitant assignment of normal polarity (dotted N) to the Aurora and Hickory Hills Till Members.

A pilot sample is shown for the Glasford Fm., the tight clustering of data as the single sample was demagnetized at progressively higher field strengths attests to the single strong component of magnetization. Unfortunately, this effect is partly due to secondary iron minerals in the sample, which necessitates further testing to thoroughly understand the history of magnetization (see text).

* Description 1 (p. 24) in Hallberg (et al.), 1980. *(sampling sites for Kellerville (subglacial) and Hickory Hills). Kellerville Member (supraglacial facies), depicted in figure 1 and discussed in text, was sampleed at the Baltimore cut (Hallberg et al., 1980, p. 65).*


Polarity
Ash Dates m.y.B.P.
Western Iowa-Eastern Nebraska
Eastern Iowa
AFTON
YARMOUTH
Rock and Soil Stratigraphy
Time-Stratigraphy Stages
WISCONSINAN
SANGAMONIAN
ILLINOIAN
YARMOUTHIAN
PRE-ILLINOIAN STAGES UNDIFF
PRE-QUATERNARY
SANGAMON PALEOSOL
Loveland Loess
Wisconsinan Loess
Glasford Frm.
Kellerville Till Member
YARMOUTH PALEOSOL
YARMOUTH-SANGAMON PALEOSOL
Hickory Hills Till Member
DYSART PALEOSOL
Aurora Till Member
FRANKLIN PALEOSOL
Winthrop Till Member
WESTBURG PALEOSOL
Undifferentiated Tills
Wolf Creek Formation
Alburnett Frm.
A_1
A_2
A_3
A_4
B
C
C
Eolian and Fluvial Deposits with Paleosols
0.6-0.7
1.2
? ?
N
N
N
N
? ?
R
?
R
?
?
R
N=Normal
R=Reversed
Polarity (This Study)
N
N
N
N
R
0
90
180
270
GLASFORD Fm. (pilot)
D_m = 358.64
I_m = 61.41
WINTHROP TILL
#SAMPLES= 4
D_m= 325.93
I_m= 47.93
K = 9.06
α_{95}=32.31
TILL
ALBURNETT Fm.
#samples=8
D_m=115.56°
I_m=-35.49°
k = 4.38
α_{95}=32.62°
SAME HORIZON
SILT (BENEATH TILL)
ALBURNETT Fm
SAMPLES = 5
D_m = 185.99°
I_m = -14.5°
k = 11.46
α_{95}= 23.6°
TILL
ALBURNETT Fm.
SAMPLES = 5
D_m = 184.29
I_m = -18.01
k = 7.99

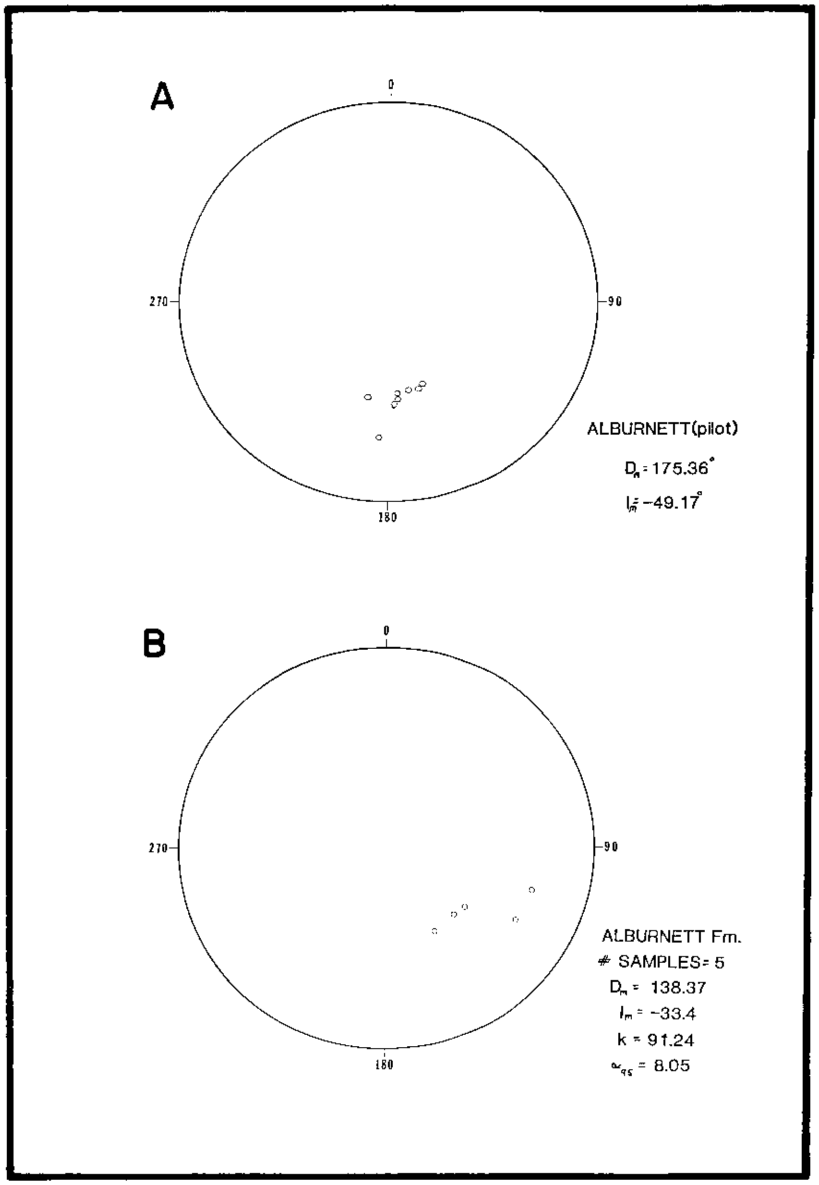


Figure 2. The sampling procedure involves excavation of an oriented block of sediment, in this case silt, of the Alburnett Fm. After controlled drying in the laboratory, the block is coated and partially impregnated in an epoxy resin. Multiple core samples are removed, and a single sample is analyzed as a "pilot" (figure 2A). The pilot sample is demagnetized at increasing field strengths* to determine the optimum level indicating the stable magnetic component. This level of demagnetization is then used for all other samples from that block (figure 2B). Scatter within-block is low for the limited number of samples, perhaps due to the easy alignment of magnetic particles into the Earth's field during settling in a quiet-water glaciolacustrine environment (e.g. Verosub, 1977).

* (Natural Remanent Magnetization (NRM), 50, 100, 150, 200, 300, 400, 500 Oe.)

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PALEOECOLOGY OF QUATERNARY SEDIMENTS AT CONKLIN QUARRY.

by Richard G. Baker, Terrence J. Frest, and R. Sanders Rhodes II
Department of Geology, University of Iowa

Two lithologic units in the Quaternary sediments at Conklin Quarry have proven to be particularly fruitful for paleoecological investigation: (1) the Wisconsinan loess and its associated sediments and (2) a newly discovered, stratified unit within the Alburnett Formation.

Wisconsinan Sediments.

The Loess.

As is usual at most loess sections of sufficient thickness in Iowa, the Wisconsinan loess contains a rich molluscan fauna, but little else. These terrestrial molluscs are present throughout its unleached thickness. Irregularly distributed lenses with greater concentrations of molluscs also are frequently encountered. Of particular note is the occurrence at Conklin Quarry of a dense "paleocolony" of the terrestrial gastropod *Oreohelix strigosa cooperi*, presently a Rocky Mountain endemic. This concentration was found just above the Late Sangamon paleosol in the lower part of the loess on an east-facing nose-slope. Unfortunately, the overburden containing this locality has since been removed. *Oreohelix* is normally quite rare in Iowa's loess. An average collecting day (at an exposure similar to that at Conklin Quarry) would yield fewer than ten specimens. In this case over 300 complete individuals were recovered in an outcrop area of less than 100 square feet (9.3 square meters), a fossil concentration heretofore unknown and one which parallels that observed at modern *Oreohelix* colonies (Frest and Rhodes, 1981).

Molluscs.-- Associated with *Oreohelix* at the colony site is a moderately diverse land snail fauna (16 species), as well as a single aquatic form, *Fossaria dalli* (Table 1). Preservation was generally good, with most specimens of *Oreohelix* and *Triodopsis* retaining original color banding, but the periostracum was not preserved. Hand collecting was used to supplement bulk sampling. About 200 lbs. (91 kg) of sediment were washed through 5, 10, 20, and 40 mesh sieves to yield about 700 identifiable molluscs. As is typical of most Wisconsinan snail faunas, that at Conklin is strongly disharmonius. Nine taxa are still Iowa residents (*Succinea ovalis*, *S. grosvenori*, *Catinella avara*, *Cochlicopa lubrica*, *Discus cronkheitei*, *Deroceras laeve*, *Euconulus fulvus*, *Triodopsis multilineata*, and *F. dalli*), but most of these have widespread distributions in North America. Iowa is presently entirely within the Interior Molluscan Province, but only one Conklin loess species, *T. multilineata*, is a characteristic Interior Province taxon. Aside from *Oreohelix*, two other species (*Vallonia gracilicosta* and *Discus shimeki*) are current Rocky Mountain endemics, while four others (*Pupilla muscorum*, *Vertigo elatior*, *V. modesta*, and *Columella alticola*) are common Northern Province elements. Also present is an extinct form (*Vertigo hannai*), as well as the Midwest Biome (Frest and Fay, 1980) relict species *Hendersonia occulta*.

Rocky Mountain and Northern forms, together with the ubiquitous succineids *C. avara* and *S. ovalis*, are numerically dominant. All of the Rocky Mountain elements are common in coniferous forest settings, but generally in forest openings. Many of the Northern species most abundant at the site are equally at

TABLE 1. Pleistocene Mollusca at Conklin Quarry.

TAXON	LOESS		CONKLIN L.B.	ANGERER L.B.
	above swale fill	*Oreohelix* colony		
Terrestrial Gastropoda:				
Oreohelix strigosa cooperi Binney	x	x	x	
Hendersonia occulta (Say)		x	x	
Cochlicopa lubrica (Müller)		x	x	
Vallonia gracilicosta Reinhardt	x	x	x	
Pupilla muscorum (Linne)	x	x	x	
Vertigo (*Vertigo*) *elatior* Sterki	x	x	x	
V. (*V.*) *modesta* (Say)	x	x	x	x
V. (*V.*) *hannai* (Pilsbry)		x		
V. (*V.*) *alpestris oughtoni* Pilsbry	x		x	x
Columella alticola (Ingersoll)	x	x	x	
Oxyloma navarrei Leonard				x
Succinea ovalis Say	x	x	x	
S. grosvenori Lea		x		
Catinella avara (Say)	x	x	x	x
Discus (*Discus*) *cronkheitei* (Newcomb)	x	x	x	
D. (*Antediscus*) *shimeki* (Pilsbry)		x	x	
Deroceras laeve (Müller)			x	x
Euconulus fulvus (Müller)	x	x	x	
Triodopsis (*Neohelix*) *multilineata* (Say)	x	x	x	
Aquatic Gastropoda:				
Fossaria (*Bakerilymnaea*) *dalli* (F.C.Baker)	x	x	x	
F. (*Fossaria*) *modicella* Say			x	
F. (*F.*) *parva* (Lea)			x	
F. (*F.*) *obrussa* (Say)				x
F. (*F.*) sp.				x
Stagnicola (*Stagnicola*) *elodes* (Say)				x
Physa skinneri Taylor				x
Gyraulus (*Torquis*) *circumstriatus* Tryon				x
G. (*T.*) *parvus* (Say)				x
Promenetus exacuosus (Say)				x
Valvata sincera sincera Say				x
Bivalvia:				
Sphaerium (*Musculium*) *lacustre* (Müller)				x
Pisidium (*Cyclocalyx*) *ventricosum* Prime				x

home in open conditions, including tundra, and in conifer and conifer/hardwood forests. Faunal diversity, the common presence of large forms such as Oreohelix, Triodopsis, and Discus, and the abundance of Northern Province species argue against a preponderance of tundra-like habitat locally. Presence of some open-ground is indicated by the unique Oreohelix colony and common D. shimeki. Xeric open-ground indicators such as V. gracilicosta and P. muscorum are rare at this site. Diversity is higher than is typical of other Johnson County Wisconsinan loess sites (about twelve species): the additional taxa are moisture-loving land species and the aquatic F. dalli. Only two taxa suggestive of Midwest Biome environments (that is, a significant deciduous forest element) are present, and they are numerically insignificant. One of these (H. occulta), as well as the Interior form T. multilineata which is also present in small numbers, is comparatively intolerant of coniferous forest cover although almost always a forest dweller.

The extinct V. hannai has been reported previously from a number of Wisconsinan localities in Kansas, Illinois, Indiana, and Ohio. In Iowa it has been found in the Wisconsinan Elkader l.b. (Woodman, 1982) and also occurs in the "Peoria Loess" of the Loess Hills, western Iowa. There it is most often found at sites dominated by Midwest Biome species, but also ranges farther north into Northern Province-dominated areas.

Additional mollusc collections were made from deoxidized loess in an area to the north and west of the Oreohelix colony, above the swale fill containing the Conklin l.b. (description below). Loess from this site was bulk sampled and washed through a standard sieve series (as detailed above). Preservation was good, but less so than at the Oreohelix colony site, or at Wisconsinan loess sites generally. Only traces of original color banding, and no periostracal preservation, were noted. Here the loess contained a reduced fauna of thirteen species (Table 1). Oreohelix is rare (fewer than ten specimens recovered) and both D. shimeki and the Midwest taxa are absent. Fossaria dalli, uncommon in the Oreohelix colony, is here more abundant, while preferentially open-ground, xeric taxa are even less common than at the last locality. Vertigo elatior, normally a minor component of relatively few loess faunas, is quite abundant. A single taxon not noted in the Oreohelix colony, Vertigo alpestris oughtoni, is represented by a few individuals. This Northern species is most often reported from cold, open-ground sites (for example, tundra) but is sometimes present in coniferous forests as well. Generally this site appears to have been less environmentally diverse than the Oreohelix colony site. Two factors may account for this lower diversity. The proportion of open-ground habitat as compared to forest appears smaller, and average available moisture was likely greater. Aside from the occurence of F. dalli and the absence of D. shimeki, the fauna of the deoxidized loess closely resembles that typical of other loess sites in Johnson County in terms of species composition. Looked at in terms of relative abundance, there are major differences. For example, the xeric open-ground-preferring taxa Vallonia gracilicosta and Pupilla muscorum, very abundant at typical sites, are here very rare, even more so than at the Oreohelix colony site.

Wisconsinan Swale Fill.

Further to the north and west (still preserved on the west wall of the quarry) is a small pocket of unoxidized, unleached sediment in a small, buried valley (or swale). This material is preserved between typically deoxidized Wisconsinan loess and the Late Sangamon paleosol. Although contemporaneous with the base of the loess, this swale fill contains coarser-grained slope-wash clasts in addition to the fine sand and silt of the loess. All of the fill sediment has been transported at least a short distance by running water to its ultimate site of deposition and therefore is crudely stratified. When freshly exposed the swale fill is a very dark grey and the underlying Sangamon paleosol is strongly gleyed (grey colors with bright greenish and bluish mottles).

Conklin Quarry Local Biota.

This deposit contains a rich assemblage of insects, terrestrial and aquatic molluscs, pollen and plant macrofossils, and rare vertebrates. Small pieces of wood (the largest about 1 cm in diameter) have been radiocarbon dated at 17,170 ± 205 RCYBP (DIC-1240). About two short tons (1800 kg) of swale sediment were washed on "window-screen" (about 1.4 mm opening) for vertebrates. All mollusc and insect remains were also picked from these coarse residues and given to the coinvestigators to augment their sample of larger-sized taxa.

Flora.-- Seven samples of sediment were processed for pollen from the basal 30 cm of the swale fill. Four of these samples contained enough pollen to count, although preservation was not particularly good. The pollen diagram is dominated by spruce (Picea), pine (Pinus), and sedge (Cyperaceae) pollen, which together average about 85 percent of the total pollen at each level. Minor amounts of birch (Betula), willow (Salix), juniper-type (Cupressaceae), and grass (Gramineae) pollen comprise most of the rest of the pollen found. Colonies of the alga Pediastrum are present at all levels. Pollen concentration is generally very low, averaging about 4000 grains/cc of sediment.

The pollen diagram is not very helpful in reconstructing the vegetation of this site. Spruce values of 15 to 20 percent indicate that this tree grew nearby. However, pine values in the same range usually indicate that pine was growing at some distant location, and not present locally. The very high sedge percentages can result from two sources: 1) sedges are common wetland plants, and high pollen percentages can result from semiaquatic species growing close to or on the site of deposition. 2) Sedges grow on the uplands in the tundra, and they could reflect upland species or both upland and lowland species if tundra was present near the site. The only species identified from microfossils that grows in the present tundra is a spikemoss called mountain moss (Selaginella selaginoides, not a true moss). Only a few microspores of this species were found in the bottom two samples of the section. The other environment that can be deduced from the pollen diagram is an aquatic habitat, based on the presence of the aquatic alga, Pediastrum.

The pollen diagram does indicate that the environment must have been quite open. Tree pollen would be much more abundant than it is in this sequence if a closed forest had been present.

Plant macrofossils are much more useful in reconstructing the past environment at the Conklin Quarry site than the pollen spectra. The sediment was sieved through U.S. Standard sieve numbers 35 and 105 sieves, and plant fragments were picked by hand from the residue.

Seeds, fruits, megaspores, and leaves representing at least 19 taxa of plants have been identified (Table 2). Six taxa are tundra species, two are tundra or boreal, two are boreal, one is boreal or temperate, and the rest are cosmopolitan. All of the cosmopolitan taxa except the awlwort are so listed because they could not be identified to species. The flora is thus mixed, but eight of the twelve taxa identified to species are tundra forms. Spruce is present as twigs, needles, and very small branches. The most likely reconstruction of the vegetation is that of a treeline environment with dwarfed spruce growing among tundra species. The other two boreal species are both weeds that can take advantages of open habitats.

TABLE 2. Plant macrofossils from the Conklin Quarry local biota.

LATIN NAME	COMMON NAME	DISTRIBUTION	HABITAT
Arenaria dawsonensis	sandwort	tundra	moist, sandy areas
cf. *Arenaria stricta*	sandwort	tundra	moist places
Betula glandulosa	dwarf birch	tundra, boreal	swamps, bogs, acidic rocks
Dryas integrifolia	mountain avens	tundra	pioneer on gravel, in heath
Juncus triglumis type	rush	tundra	calc. sand, clay pond margins
Saxifraga aizoides	yellow mt. saxifrage	tundra	moist, calc. clay, gravel
Selaginella selaginoides	spikemoss	tundra, boreal	muskeg, mossy areas
Silene acaulis	moss campion	tundra	sandy soil, rocky areas
Picea	spruce	boreal	forest,scrub
Polygonum anchoreum type	smartweed	boreal	waste places
Chenopodium leptophyllum	pigweed	boreal, temp.	waste places sandy soil
Subularia aquatica	awlwort	cosmopolitan	silty bottom of clear ponds
Carex spp.	sedges	cosmopolitan	wet places, arctic uplands
cf. *Cardamine*	bitter cress	cosmopolitan	wet places
other Cruciferae	mustards	cosmopolitan	variable
Juncus sp. A	rush	cosmopolitan	wet places
Juncus spp.	rushes	cosmopolitan	wet places
Salix	willow	cosmopolitan	wet places, arctic uplands

The habitats present included a clear pond with a silty bottom, pond margin, moist calcareous sites, mossy areas, swampy or boggy areas, and disturbed, gravelly areas. All these could have been present close to the Conklin Quarry site. The mosses, identified by Dr. Jan Janssens, Limnological Research Center, University of Minnesota, support the habitats postulated by the higher plants.

Insects.-- A large and diverse group of insects is present in the Conklin Quarry local biota. They have been identified by Dr. Don Schwert, Department of Geology, North Dakota State University, Fargo. He finds that the largest group is the carabid beetles, a group of ground beetles particularly useful in reconstructing past environments. Details of the interpretation of the insect fauna are in preparation, but the most important geographic element are those now found in the Alaskan tundra. Although a few taxa in the fauna are found in the boreal forest today, none of the bark beetles or other groups typical of forested environments are present. The insect fauna also presents us with a view of a very open tundra environment, perhaps with a few scattered trees.

Molluscs.-- The sieving of large amounts of swale material on coarse screen (1.4 mm mesh) for vertebrates produced very large numbers of molluscs. A smaller quantity of sediment was washed through a screen series (as above) to ensure adequate representation of small taxa. Preservation was exceptional, with many specimens retaining portions of the periostracum as well as color banding. The 19 gastropods of the Conklin l.b. make it the most diverse fossil mollusc fauna yet reported in Johnson County (Table 1). In general aspect it is much like that of other Wisconsinan loess sites in the county. Northern and Rocky Mountain species, plus *Hendersonia occulta*, are important elements. This assemblage is more diverse than those at more northerly, tundra-like sites in the Iowa Paleozoic Plateau and around the periphery of the Des Moines Lobe. Midwest or Interior elements (characteristic of largely deciduous forests) are either minor or absent, and the diversity is less than would be characteristic for southeastern or southwestern Iowa "Peoria Loess" sites. There are, however, some important differences from typical Johnson or Linn County, Ia., localities. *Oreohelix* is very rare (four specimens found out of tens of thousands of picked snails). *Vertigo alpestris oughtoni* is present in significant numbers along with *V. modesta*, but *V. elatior* is uncommon. Among the succineids *Catinella avara* (*Succinea gelida* of some authors) is very abundant - the most common taxon in the fauna - while *S. ovalis* is prominent: at most sites located a similar distance from the presumed ice margin, *S. ovalis* dominates the fauna. Xeric open-ground taxa are very rare, and moisture tolerant forms are of increased importance. Aquatics are exceptionally abundant. *Fossaria dalli* is nearly as common as *C. avara*, and one other full aquatic, *F. modicella*, is also present, as is the amphibious species *F. parva*. The slug *Deroceras laeve* is common in the swale fill but absent from the other Conklin loess sites. Discounting the succineids and aquatics, the small northern (tundra/coniferous forest) pupillids *Columella alticola*, *V. modesta*, and *V. alpestris oughtoni* are very abundant, while the larger Rocky Mountain snails *Oreohelix* and *Discus shimeki* are less common. This reverses the situation noted for the *Oreohelix* colony. The Interior species *Triodopsis multilineata* and the Midwest *H. occulta* are present but rare, suggesting possible limited persistence of some deciduous trees.

Although aquatic gastropods are both more abundant and more diverse at this site than is usual for Wisconsinan loess sites, terrestrial forms in aggregate are more abundant. The swale itself probably represents a very moist environment with some standing water. Aquatic diversity is too low to suggest a permanent ponding, and a muskeg pool is perhaps the closest modern equivalent.

Generally the assemblage indicates a tundra/treeline environment, but with rather more available moisture than present in such an environment today. Compared to other Wisconsinan loess sites in the vicinity, the Conklin Quarry sites appear to have been not only less xeric, but also less open. Elements of the unusually diverse mollusc fauna suggest the persistence of sizeable conifer and even hardwood stands, as well as tundra-like patches, in the immediate vicinity. Marked differences in molluscan faunal composition from sites of similar age within a few hundred meters of each other suggest that a rich mosaic, composed of partial analogues to modern environments which are widely separated today, may have been characteristic of some parts of the Iowa Late Pleistocene landscape. Given its presumed physical situation, the Conklin l.b. probably most adequately represents the full range of both the environments present and the total molluscan diversity in the county as a whole even though it is evidently unusually moist and thus environmentally atypical.

Vertebrates.-- The Conklin Quarry l.b. yielded the remains of at least twelve different vertebrate individuals (based upon all remains). This small sample size makes interpretation of the fauna difficult. Permanent water must have been nearby since a fish vertebra was found. An unidentified bird is represented by eggshell fragments and this indicates that the summer climate was mild enough to allow nesting behavior (prominent today as far north as the tundra). The most common mammalian fossils are coprolites (fossil scats) of a small vole- or mouse-sized mammal. A very dense concentration of these scats (washing out at the surface of the exposure) initially drew attention to this horizon. This concentration perhaps represents a fossil "toilet station" in a Wisconsinan runway or burrow system. The scats are less frequent in the bulk of the deposit, but they are found in low concentration throughout the unoxidized swale fill.

Microtine rodents provide most of the bones recovered. Voles of the genus Microtus are the most common mammals. The meadow vole (Microtus pennsylvanicus), yellow-cheeked vole (Microtus xanthognathus), and possibly singing vole (Microtus miurus) are all present. The singing vole is questionable for the following reasons: its distant present-day distribution (Alaska and the Yukon), the occurence of confusingly similar teeth in other voles of the genus Microtus, and the small number of elements recovered to date from the swale fill (only 22 Microtus teeth altogether).

The heather vole (Phenacomys intermedius) and collared lemming (Dicrostonyx) are represented by dental remains sufficiently complete to document their presence in the swale fill. The red-backed vole (Clethrionomys) and eastern chipmunk (Tamias striatus) are present but less certainly diagnosed because of scanty material. A rabbit-sized or larger mammal is present, but can not be further identified.

Only two of the seven identified mammals currently live in Johnson Co., Ia. (meadow vole and eastern chipmunk), an additional taxon occurs as far south as Pilot Knob in north-central Iowa (red-backed vole). The meadow vole, as its name implies, inhabits densely grass-grown meadows. The eastern chipmunk prefers open forest or the shrubby forest-edge of the present deciduous forest but penetrates into the eastern boreal forest as far north as Hudson Bay. The red-backed vole is boreomontane in distribution and favors forests with good litter accumulations. The ranges of the yellow-cheeked vole and heather vole are boreal and boreomontane, respectively. Both are more or less associated with coniferous forest of variable density. The collared lemming and singing vole are at present strictly arctic mammals. Both are inhabitants of open ground in the modern tundra.

These seven mammals do not presently co-occur in any single geographic area (that is, the mammals are disharmonious). At most, five of the seven live together, in various combinations, along the tundra/forest border in Canada. This modern distribution suggests that the Wisconsinan climate of southeastern Iowa was both drier and much colder than the present climate. Nonetheless, the persistence of the relatively temperate/mesic eastern chipmunk indicates that Wisconsinan conditions were more moderate than those at the present tundra/forest border. The lack of a perfect modern analogue for this mammalian local fauna suggests that neither Wisconsinan climates nor biotas were the result of simple southward displacement of the modern climatic zones and biomes.

Larger faunas, both to the east and west, document a much greater mammalian diversity during the Wisconsinan than that of the Conklin Quarry local biota. In Mills Co., southwestern Iowa, the Craigmile l.f. (23,240 ± 535 RCYBP) yielded 31 mammalian taxa and the Waubonsie l.f. (14,850 + 1060, - 1220, RCYBP) yielded 23 taxa (Rhodes, in press). Both are disharmonious, dominated by open ground mammals, and show a mixture of invaders from the northwest with many present-day inhabitants of southwestern Iowa. Both lack tundra-specific mammals. The vegetation probably formed a mosaic of grasslands and forest patches at each interval but was more forested during Waubonsie time than Craigmile.

The Moscow Fissure l.f. (Iowa Co., southwestern Wisconsin; 17,050 ± 1500 RCYBP; Foley, in press) contains 21 taxa of mammals. It also documents a mosaic of open-ground and forested habitats, but more forest indicators are present than in southwestern Iowa. This site does contain a taxon indicative of tundra, the collared lemming. Another small local biota, the Elkader l.b. (Clayton Co., northeastern Iowa; 20,530 ± 130 RCYBP; Woodman, 1982) yielded only 17 individuals but it also confirms the presence of the collared lemming in the upper Midwest. Moreover, the Elkader l.b. contains questionable remains of the singing vole and positively identified remains of the arctic ground squirrel (<u>Spermophilus</u> <u>perryii</u>) which makes it the most "arctic" fauna found in the lower 48 states. Neither the Conklin Quarry l.b. nor the Elkader l.b. have a large enough sample to define a geographic area or time period of reduced mammalian diversity like that which might be expected if glacial climates were severely cold. Nonetheless, both <u>do</u> indicate the presence (at least) of microclimates severe enough to produce local conditions like those on the modern tundra.

Summary.-- The Conklin l.b. definitely documents a tundra/tree-line assemblage of plants and animals in eastern Iowa about 17,000 years ago. A true tundra environment existed in the coldest of these Wisconsinan habitats. Nonetheless, patches of conifers (and probably boreal hardwoods) managed to survive in favorable exposures.

<u>Pre-Illinoian Sediments</u>.

Alburnett Formation Lower Stratified Horizon.

A discontinuous pod of fossiliferous sediment was discovered in 1983 sandwiched between two Alburnett diamicton units near the base of the Quaternary section in Conklin quarry. The lowest Alburnett diamicton (predominately sheared Pennsylvanian shale at its base) changes gradually upward into stratified sands and silts. In its upper portions this stratified material is both highly contorted and strongly variable in grain size. Coarse pebble and granule beds occur less than a meter away ("horizontally") from fine sand and silt beds. The entire contorted, stratified unit is capped by a level, uncontorted bed of highly acidic, humified peat and organic-rich sediment. This is in turn overlain by a younger Alburnett diamicton. A highly fossiliferous pod of layered fine sand and silt was found within the "upper" 20 cm of this stratified unit. The length of the fossil-bearing pod was only 10 meters. Although generally finer grained than normal for the top of the stratified unit, pebbles up to 2.5 cm in diameter were observed during screening for fossils. Some of the beds in this fossil deposit were so rich in mollusc and Chara fragments that they resembled lacustine marls. A smaller pod, no more than 2 m long, was also seen about 40 m south of the excavation site.

Angerer Local Biota.

Only the larger fossiliferous pod has been sampled. About 900 lbs (410 kg) has been washed on a No. 35 sieve (0.5 mm opening). Smaller subsamples were washed for microfossils on sieves as fine as No. 230 (0.063 mm opening). A large assemblage of fossils has been recovered and includes charophyte debris (oogonia and stem fragments of a lime-depositing, freshwater alga), pollen, plant macrofossils (mostly seeds of aquatic plants), lacustrine molluscs, rare terrestrial molluscs, numerous ostracod shells, rare insect fragments (possibly contamination), and very rare vertebrate remains. Study of this unit has just begun and only preliminary results are here reported.

Flora.-- The pollen of this biota has not been carefully counted, but a preliminary count of one level, and scans of other levels, suggests that the sequence is dominated by pollen of spruce, larch, and pine. Birch and oak are also present in low percentages. Sedges are by far the most abundant of the herbs, but grass and sagebrush pollen also are present. Pollen of water-milfoil, cattail or bur-reed, and spores of scouring rush represent the aquatic plants.

The three important trees in the pollen spectrum (spruce, larch, and pine) are the three dominant species in the present boreal forest. They suggest that a similar forest was present when these Alburnett sediments were being deposited. The presence of deciduous-tree pollen suggests that a few oak and birch may also have been present, and that the southern boundary of the conifer forest may have been somewhere in the region. The herb pollen indicates that some open areas were present in the forest.

The plant macrofossils are almost entirely of aquatic species. They are predominantly pondweeds, sedges, water-milfoil, and an unknown taxon. These fossils indicate that a shallow pond was present at the site. Pond-margin plants like scouring-rush (from spores in the pollen count) and sedges suggest that the shore of the pond was not far away. The general interpretation of the plant evidence indicates that the site was a shallow pond in a boreal forest very similar to that of the present.

Invertebrates.-- The invertebrate fauna of the Angerer l.b. includes abundant molluscs and ostracods, as well as less common insect parts. Only the molluscs have been examined so far. Preservation is variable: most specimens of most taxa have etched exteriors, and channeling from rootlets is frequent. Fine details of surface ornament are generally lacking, but this has hampered identification in relatively few instances. To date, 15 taxa have been identified (Table 1), comprising 8 aquatic snails, 2 bivalves, and 5 terrestrial snails. Land snails are rare, with only a single taxon (Catinella avara) represented by more than one or two specimens. Collectively, the species found suggest a moist, open-ground situation such as would be expected along or near a shoreline: they are all types likely to find their way in very small numbers into a lake or pond. The small proportion of land snails found indicates that the excavated area represents a near shore but not shoreline situation. Two land species, *C. avara* and *Deroceras laeve*, are currently resident in Johnson County. *Vertigo alpestris oughtoni* and *V. modesta* are Northern Province forms common in tundra and coniferous forest environments. *Oxyloma navarrei* is an extinct form described by Leonard (1950) from the "Pearlette Ash" (including localities in the Hartford Ash of current usage) in Kansas. Presumably its environmental requirements are similar to those of the extant *O. retusa*, a common swamp and meander-lake border snail in Iowa.

Most of the aquatic species are widely distributed forms that are part of the modern Iowa fauna: the exceptions are *Physa skinneri*, *Gyraulus circumstriatus*, *Valvata sincera sincera*, and *Pisidium ventricosum*, which are more northern in distribution. None are obligate deep-water species, and most are broadly tolerant, capable of living in a variety temporary and permanent habitats. An exception is *G. circumstriatus*, rare in this deposit, which is reported by Clarke (1973, 1981) to be characteristic of vernal habitats in Canada. The presently very common, permanent-water species *Gyraulus deflectus* appears to be absent from the Angerer l.b. *Valvata sincera sincera*, a common species at this site, is generally found in sizeable permanent lakes at considerable depth but can inhabit shallower water at the northern limit of its range, that is, central Manitoba and Saskatchewan to northern Alberta and the Northwest Territories of Canada (Clarke, 1981).

The majority of the aquatic species prefer muddy bottoms with moderate to dense growths of submerged aquatic vegetation. *Physa skinneri* and *V. sincera sincera*, obligate cold-stenothermal types, and the land snail species *V. modesta* and *V. alpestris oughtoni* are suggestive of an environment somewhat more cool but less moist than that proposed for many Hartford Ash sites. This cooler environment is perhaps analogous to that of the Little Sioux l.f. (Paulson and Miller, 1983). These taxa, together with *G. circumstriatus*, may indicate a cool boreal climate similar to that in present-day Alberta, southern Saskatchewan, and southern Manitoba. In these areas Clarke (1973) reports the frequent association of *G. circumstriatus* with *G. parvus*, *P. skinneri*, *P. gyrina*, *Stagnicola elodes*, *S. caperata*, and *Sphaerium lacustre*. All of these except *P. gyrina* and *S. caperata* are common at the fossil site. Compared to other "Pearlette" localities, the Angerer l.b. contains relatively few, and very rare, extinct taxa despite its presumed age. *Oxyloma navarrei* is represented by a single specimen; *Fossaria* sp. may be a new, and presumably extinct, taxon. The prevalence of extant forms may be related to the apparently more boreal aspect of this fauna (compared to other sites of this age).

Despite the presence of rare *G. circumstriatus*, the fauna as a whole suggests a shallow, semipermanent, mud-bottomed pond with abundant aquatic vegetation. This pond was situated in a cool, moist boreal forest closely analogous to that of parts of modern southern Canada. The Angerer malacofauna is much less disharmonious than those of the Wisconsinan-age Conklin sites, and appears to have closer modern analogues than do sites of similar antiquity elsewhere in the Midwest.

Vertebrates.-- Although the residues are only partly picked, eggshell fragments, pieces of mammal bone, and one marginally diagnostic mammal tooth have so far been recovered. This tooth (an upper first molar) belongs to a vole of the genus *Microtus* but can be identified no further. It is not yet known whether the density of mammal fossils is great enough to be exploited, but the very occurence of small mammals in direct association with pre-Illinoian glacial sediments warrents further sampling. The Angerer l.b. may provide an unparalleled opportunity to link the lithostratigraphic record of Iowa's pre-Illinoian glacial diamictons with the biostratigraphic record of pre-Illinoian vertebrates on the Great Plains (see Hibbard, 1970).

Summary.-- Although the biota is not yet completely analyzed, separate evidence from plant macrofossils, pollen, and molluscs provides a remarkably congruent environmental interpretation of the Angerer local biota. The site was most likely a shallow weedy pond or lake surrounded by an open, conifer-dominated forest similar to that of the coniferous forest-prairie border in modern southern Canada.

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Geological Society of Iowa
109 Trowbridge Hall
Iowa City, Iowa 52242-1319
http://www.igsb.uiowa.edu/gsi/