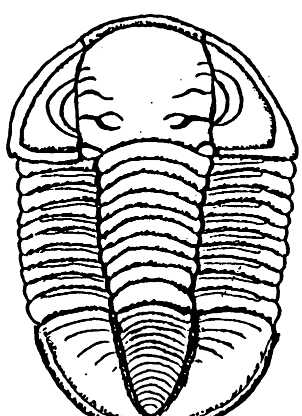
THE STRATIGRAPHY, PALEONTOLOGY, DEPOSITIONAL AND DIAGENETIC HISTORY OF THE MIDDLE-UPPER DEVONIAN CEDAR VALLEY GROUP OF CENTRAL AND EASTERN IOWA

GUIDEBOOK SERIES NO. 16



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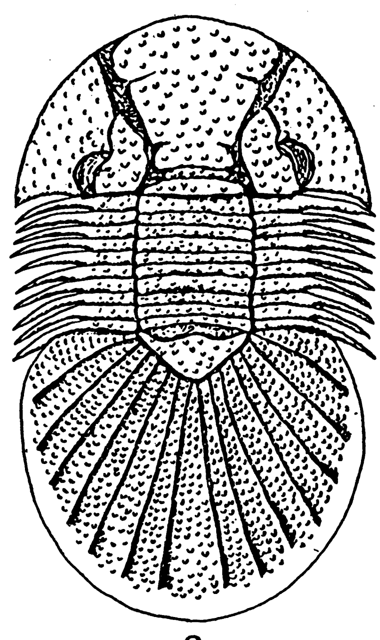

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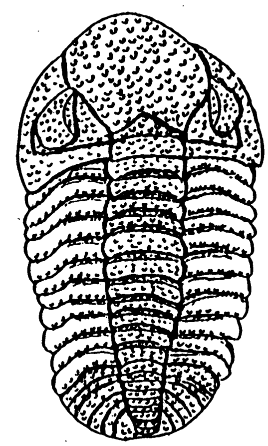

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Iowa Department of Natural Resources
Larry J. Wilson, Director
May 1992

Cover illustration: 1. *Crassiproetus arietinus*, 2. *Scutellum (Scutellum) depressum*, and 3. *Phacops iowensis iowensis* (trilobites from the Solon Member, Little Cedar Formation; Hickerson, this guidebook fig. 3).

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THE STRATIGRAPHY, PALEONTOLOGY, DEPOSITIONAL AND DIAGENETIC HISTORY OF THE MIDDLE-UPPER DEVONIAN CEDAR VALLEY GROUP OF CENTRAL AND EASTERN IOWA

Guidebook Series No. 16

edited by

Jed Day
Department of Geography-Geology
Illinois State University
Normal, Illinois 61761

and

Bill J. Bunker
Geological Survey Bureau
Energy and Geological Resources Division
Iowa Department of Natural Resources

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Larry J. Wilson, Director

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by

Bill J. Bunker and Brian J. Witzke
Iowa Department of Natural Resources
Geological Survey Bureau
Iowa City, Iowa 52242

INTRODUCTION

Epicontinental seaway shelves are generally characterized by repetitive episodes of progradation, punctuated by periods of transgression and subsequent flooding of the seaway margins. These episodes are generally recognized along epicontinental shelves as transgressive-regressive (T-R) cycles. The basic stratigraphic framework of the Iowa Middle Devonian Wapsipinicon and Cedar Valley groups are defined as a series of carbonate T-R cycles (Witzke et al., 1988), which occur along the western margin of the Middle to Late Devonian Chattanooga Sea. These sequences in the Upper Midwest occur in an area that has been termed the Midcontinent Carbonate Shelf by Slingerland (1986), who modelled tidal effects in the Late Devonian seaway. A conodont zonation scheme for cratonic biofacies in eastern Iowa has also been developed (Bunker and Klapper, 1984; Witzke et al., 1985; Witzke et al., 1988), which provides a basis for correlation in the Midcontinent Carbonate Shelf area.

Devonian strata in Iowa and surrounding areas unconformably overlie an eroded surface of Ordovician and Silurian rocks (Fig. 1). Upper Devonian strata onlap onto the Precambrian surface adjacent to the Sioux Ridge in northwestern Iowa (Fig. 1). Devonian strata in the central Midcontinent region are bounded to the north by the Transcontinental Arch (including the Sioux Ridge), to the west by the Cambridge Arch-Central Kansas Uplift, to the south by the Chautauqua Arch-Ozark Uplift-Sangamon Arch, and to the east by the Devonian outcrop belt and sub-Pennsylvanian Devonian edge (Figs. 1, 2). Devonian strata extend across the Transcontinental Arch in the area of the Nebraska Sag (Fig. 1). Devonian seaways may also have breached the arch to the east of the resistant highlands of the Sioux Ridge in central Minnesota, but pre-Cretaceous erosion apparently removed Devonian strata from that area. The East-Central Iowa and North Kansas basins (Fig. 1) are primarily Silurian features, but persisted as structural depressions during the initial stages of Middle Devonian (late Eifelian-early Givetian) deposition in the region. Eifelian deposits are restricted to these two basin areas and are absent from intervening areas in central and western Iowa. Late Givetian and Frasnian strata thicken markedly toward central and northern Iowa, where the thickest sequences of Devonian strata in the region are preserved (to 230 m). Total Devonian isopachs delineate this area as a stratigraphic basin (Fig. 2), termed the Iowa Basin by Witzke et al. (1988). Although the thick accumulation of Devonian strata in the Iowa Basin delineates a region of significant Devonian subsidence, deposition in this basin area was dissimilar to that in the central Illinois Basin. As will be discussed, the Iowa Basin encompassed an area of extensive shallow-marine, tidal-flat, and evaporite deposition during the late Middle through lower Upper Devonian. Depositional interpretations indicate that consistently shallower-water depositional facies are found in the central area of the Iowa Basin than are found in either southeastern Iowa or in the central Illinois Basin, and as such it is not considered to be a bathymetric basin during Devonian deposition (Witzke et al., 1988). By contrast, the Illinois Basin was a site of relatively deeper-water epicontinental sedimentation during much of the Devonian (Witzke, 1987). The central Illinois Basin is regarded, therefore, as both a bathymetric and a stratigraphic basin.

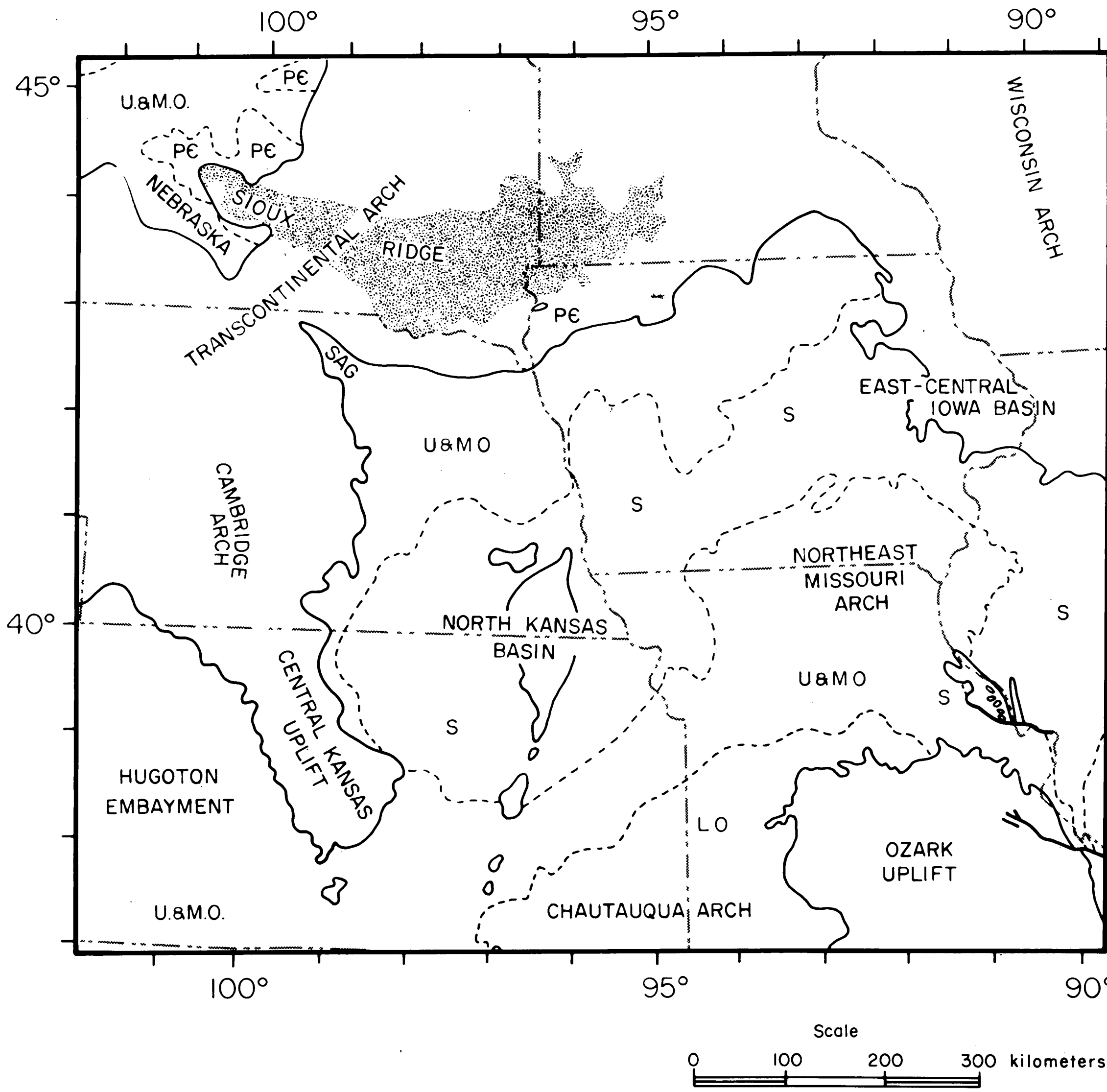


Figure 1. Pre-Kaskaskia paleogeologic map of the central midcontinent region, U.S.A. (from Bunker et al. 1988). P-Precambrian; LO-Lower Ordovician; U&MO-Upper & Middle Ordovician; S-Silurian.

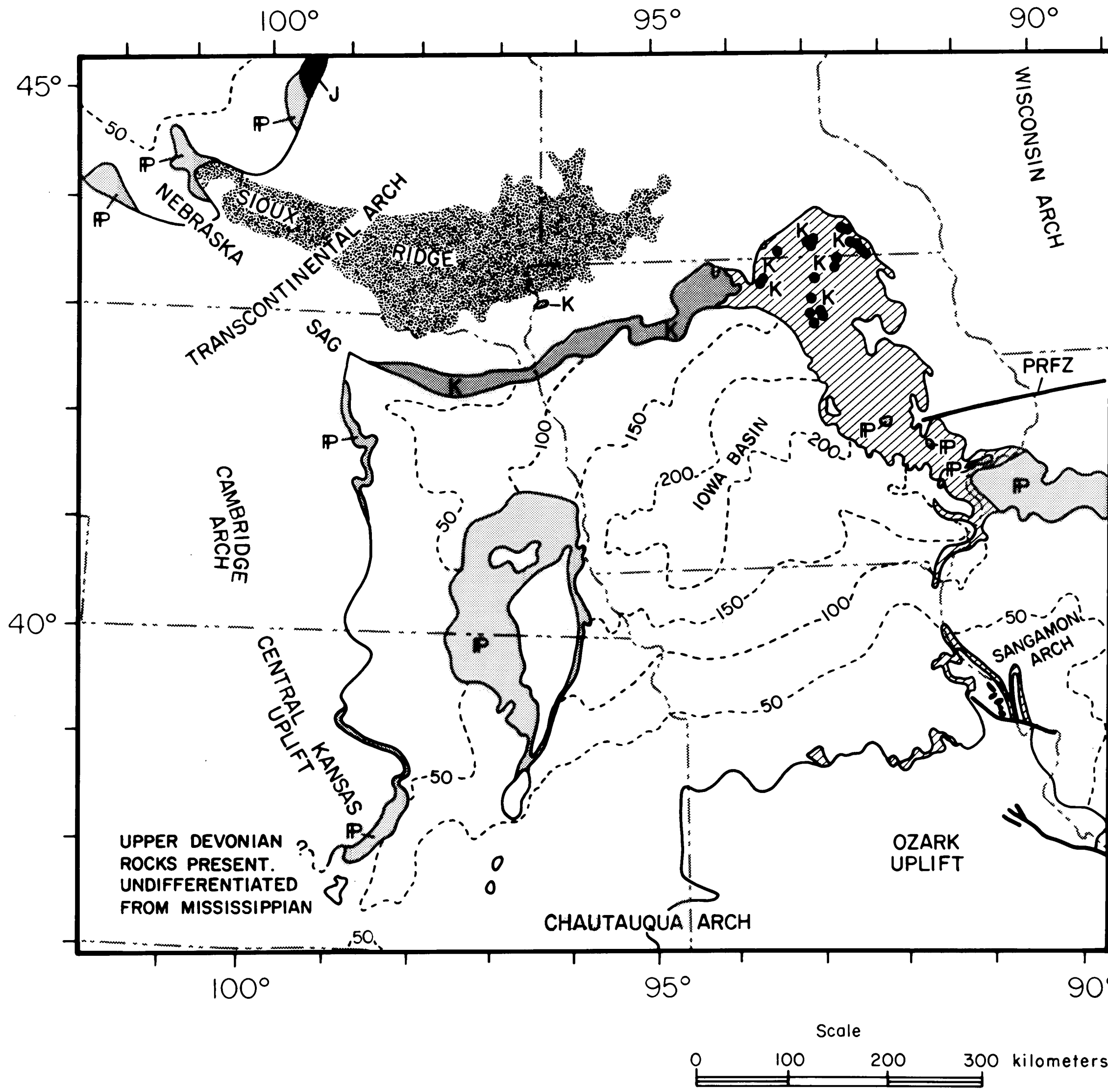


Figure 2. Total Devonian isopach map of the central midcontinent region, U.S.A. (from Bunker et al., 1988). Contour interval is 50 m. Patterned areas denote where Devonian strata have been eroded and overstepped by younger strata. P-Pennsylvanian; J-Jurassic; K-Cretaceous; diagonally-lined areas denote present day outcrop. PRFZ-Plum River Fault Zone.

STRATIGRAPHY

Wapsipinicon Group

The Wapsipinicon Formation was named by Norton (1895) for exposures along the Wapsipinicon River in northeastern Linn County, Iowa. It was elevated to group status by Witzke et al. (1988) to include, in ascending order, the Bertram, Otis, and Pinicon Ridge formations in eastern Iowa, and the Spillville and Pinicon Ridge formations in northern Iowa and southeastern Minnesota (Fig. 3).

The Wapsipinicon Group overlies an erosional surface on Ordovician and Silurian strata (Fig. 1) and is overlain disconformably by the Cedar Valley Group over its regional extent in Iowa, western Illinois, northern Missouri, and southeastern Minnesota. Its edge is overlapped by Cedar Valley strata to the west and south. The Wapsipinicon Group reaches thicknesses of up to 60 m south of the type area adjacent to the Plum River Fault Zone (Fig. 4), and is dominated by carbonate rock, but gypsum and anhydrite are significant components in southern and central Iowa (Fig. 4). The group encompasses two major T-R depositional cycles.

Cedar Valley Group

Owen (1852) termed the Middle Devonian carbonate sequence of eastern Iowa the "limestones of Cedar Valley," and McGee (1891) formally designated this interval the "Cedar Valley limestone." Subsequent definition of the Wapsipinicon Formation restricted the Cedar Valley Limestone to the interval above the Wapsipinicon and below the Upper Devonian shales of the Sweetland Creek and Lime Creek formations. The Cedar Valley was elevated to group status (Witzke et al., 1988) to include four formations, each corresponding to a major T-R cycle of deposition, and each separated from adjacent formations by an erosional unconformity or discontinuity surface. The constituent formations are, in ascending order, the Little Cedar, Coralville, Lithograph City, and Shell Rock (Fig. 3).

No type locality for the Cedar Valley Limestone was ever designated, but a primary reference section at Conklin Quarry near Iowa City has been proposed (Bunker et al., 1985). Where overlain by the Sweetland Creek or Lime Creek formations, the Cedar Valley Group varies considerably in thickness, ranging from 23 to 40 m in southeastern Iowa and reaching maximum thicknesses of 80 to 120 m in northern and central Iowa. The Cedar Valley Group disconformably overlies the Wapsipinicon Group over much of its extent, but Cedar Valley strata overlap the Wapsipinicon edge to the south and west to overstep Ordovician or Silurian rocks in parts of northern Missouri, northern Illinois (Collinson and Atherton, 1975), and western Iowa (Figs. 1, 5). The Cedar Valley Group is dominated by fossiliferous limestone in southeastern Iowa and northern Illinois, by dolomite and limestone in northern Iowa, and by dolomite and anhydrite in central Iowa.

Little Cedar Formation

The Little Cedar Formation (Fig. 3) includes lower Cedar Valley strata which are bounded below by the Wapsipinicon Group (or Ordovician-Silurian rocks where the Wapsipinicon is absent) and above by the Coralville Formation. The type locality is at the Chickasaw Park Quarry (Witzke et al., 1988) adjacent to the Little Cedar River in southwestern Chickasaw County, Iowa; this locality exposes one of the most complete sections (17 m) of the formation in northern Iowa. The Little Cedar Formation ranges from 15 to 37 m in thickness; it is thinnest in southeastern Iowa and thickest in northern and central Iowa. The Coralville overlies a disconformity or discontinuity surface at the top of the Little Cedar Formation at most localities. However, the Lithograph City Formation is locally incised into the Little Cedar Formation in parts of Johnson County and the Sweetland Creek Shale overlies the formation at a few localities in southeastern Iowa. The Little Cedar Formation is interpreted to have been deposited during a large-scale T-R cycle (part of cycle IIa of Johnson et al., 1985), the Taghanic Onlap (Johnson, 1970). The formation is subdivided into three to four members in northern and central Iowa (in ascending order, Bassett, Chickasaw Shale, Eagle Center, and Hinkle) and two members in southeastern Iowa (Solon and Rapid). Subsequent discussion of the constituent members defines lithologic variations within the formation.

Solon Member. The Solon Member (Fig. 3) is dominated by fine skeletal muddy calcarenite (biomicrite and some biosparite) with scattered shaly or carbonaceous partings (Kettenbrink, 1973). Argillaceous calcilutite is present, especially near the northern limits of the member. Hardgrounds are developed locally. A thin sandy limestone is commonly present at the base; this sandy interval locally includes sandstone facies (Hoing Sandstone) in parts of northern Missouri and western Illinois (Collinson and Atherton, 1975; Tissue, 1977). The basal contact is disconform-

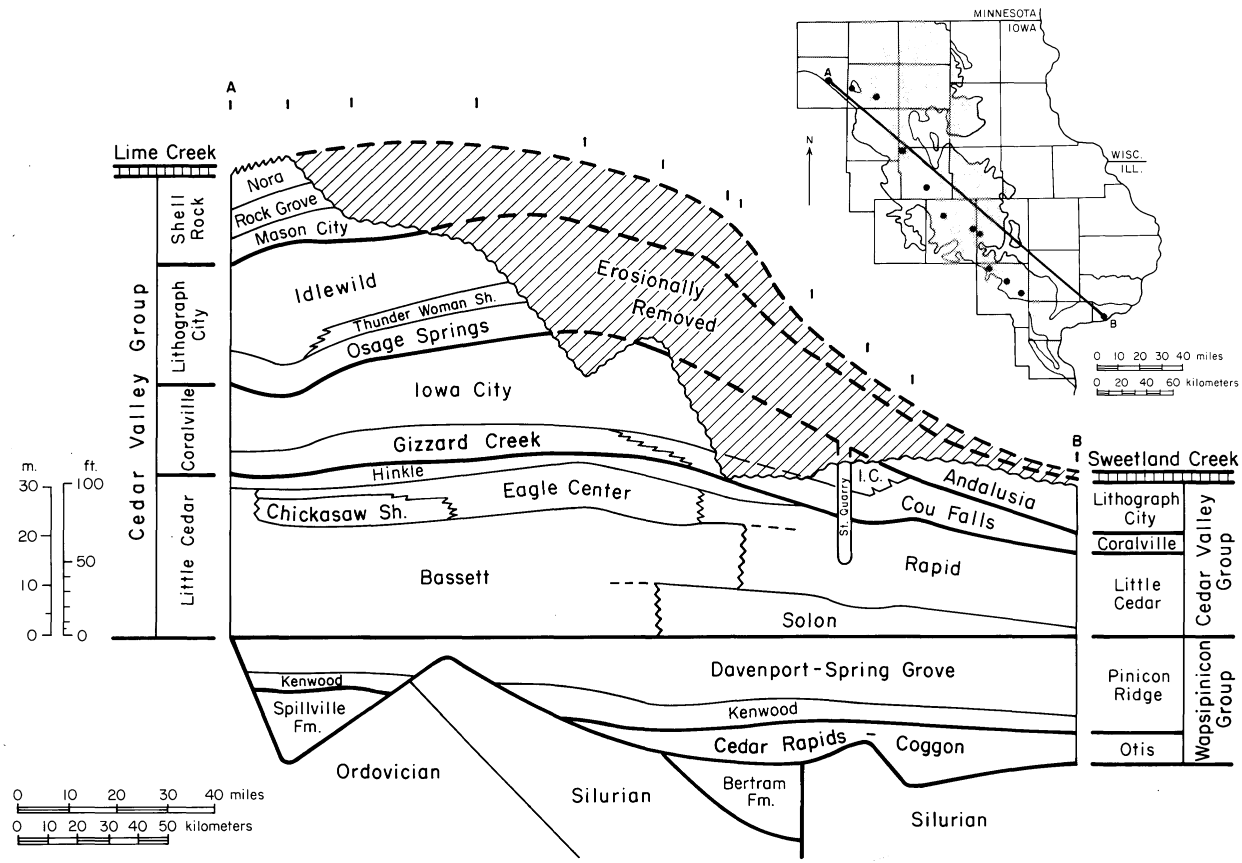


Figure 3. Generalized stratigraphic cross-section from north-central to extreme east-central Iowa, showing interpreted stratigraphic relationships of the various units of the Wapsipinicon and Cedar Valley groups (from Witzke et al., 1988).

able, but the upper contact with the Rapid Member is variably gradational or sharp (locally a burrowed discontinuity surface or hardground). The Solon Member is limited geographically to areas of east-central and southeastern Iowa and adjacent areas of northern Missouri and Illinois. The member varies from 1.5 to 12 m in thickness and is thinnest to the southeast. It generally thickens to the north, and skeletal calcarenites of the Solon are replaced by argillaceous dolomites of the lower Bassett Member in that direction.

Conodont faunas of the Solon span the upper Middle *varcus* through Lower *hermanni* (redefined by Klapper & Johnson, 1990) subzones (Bunker and Klapper, 1984; Witzke et al., 1985, 1988). The macrofauna of the Solon is abundant and diverse including brachiopods (Stainbrook, 1941a; Day, this guidebook), and corals and stromatoporoids (Stainbrook, 1941a; Mitchell, 1977), whose stratigraphic significance are described in further detail in Witzke et al. (1988).

Rapid Member. The Rapid Member (Fig. 3) is dominated by argillaceous calcilutite (ranging from micrite to sparse biomicrite), but shaly partings and lenses of calcarenite interbed with the sequence. The Rapid is divided into three widely recognizable descriptive lithologic units: 1) a lower fossiliferous calcilutite interval (some calcarenite) with common shaly partings ("*bellula* zone" of Stainbrook, 1941a); 2) a middle unit ("*Pentamerella* beds" of Stainbrook, 1941a) composed of interbedded fossiliferous calcilutite (some calcarenite) and unfossiliferous to sparsely fossiliferous burrowed calcilutite; this unit is capped by two widespread coralline biostromes (Zawistowski, 1971) and locally includes concentrations of glauconite and apatite pellets in some beds; and 3) an upper

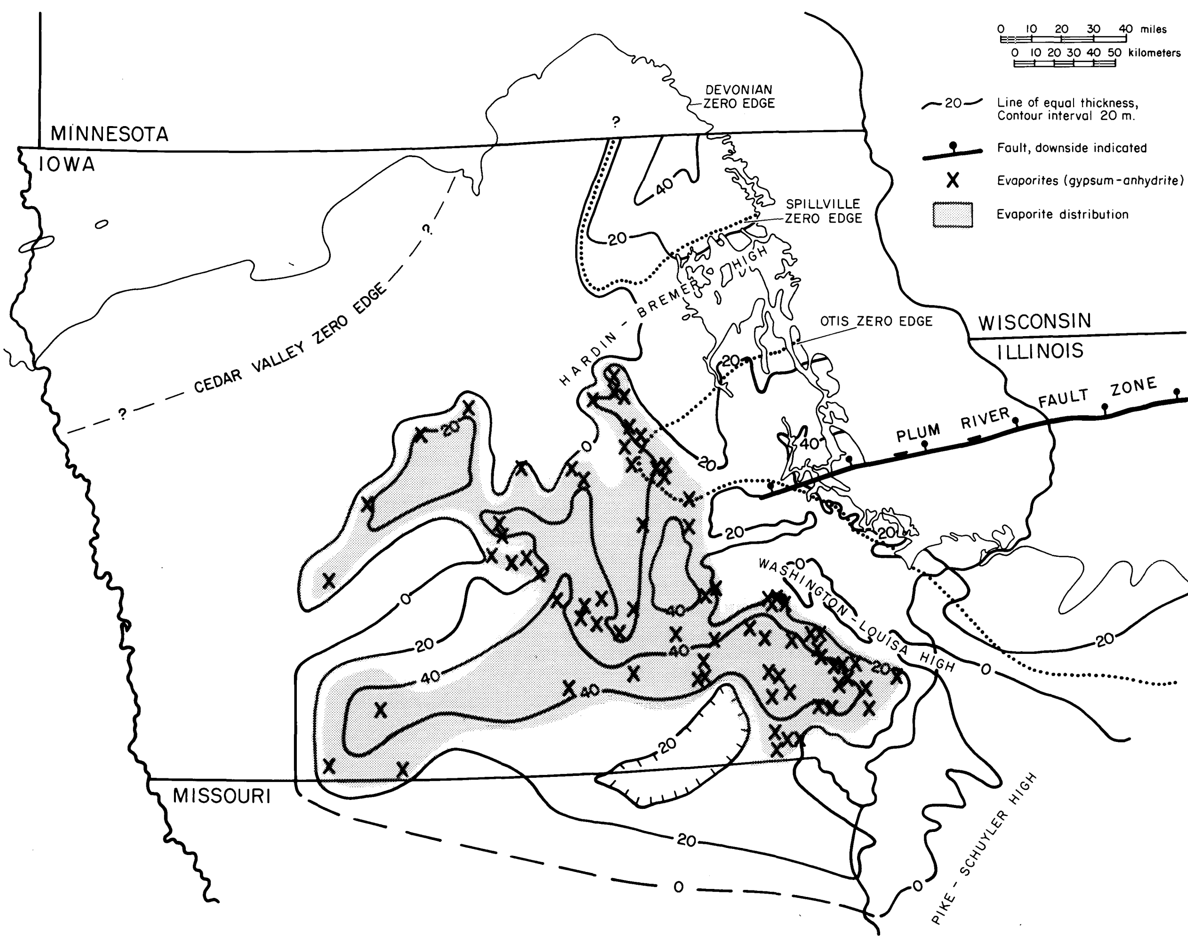


Figure 4. Isopach and evaporite distribution map of the Wapsipinicon Group (from Witzke et al., 1988).

unit ("*waterlooensis* zone" of Stainbrook, 1941a) of fossiliferous calcilutite interbedded with lenses of echinoderm-rich calcarenite (packstones and grainstones to the north). The upper unit is glauconitic (in the lower half) in the type Rapid area, and is commonly cherty with prominent hardgrounds. The upper Rapid displays a greater degree of thickness and facies variations than is noted in the lower and middle strata; it varies in thickness from about 2 m in the south to 5 m in the north.

The Rapid Member conformably overlies the Solon, but its upper surface is marked by a widespread burrowed discontinuity surface over most of its geographic extent. It is sharply overlain by calcarenites of the Coralville Formation except near its northern limits where it is conformably overlain by the Hinkle Member (Fig. 3). The State Quarry Member of the Lithograph City Formation is locally incised into the Rapid in the type area, and the Sweetland Creek Shale overlies the Rapid at a few localities in the subsurface of extreme southeastern Iowa. The Rapid Member is recognized across southeastern and east-central Iowa and adjacent areas of western Illinois and northeastern Missouri. It is relatively uniform in lithology and thickness over its geographic extent, ranging in thickness from 13.5 to 18 m. The Rapid Member is replaced north of Palo by strata of the middle and upper Bassett, Chickasaw Shale, Eagle Center, and Hinkle members. The Solon and Rapid members are replaced southward in western Illinois and northern Missouri by skeletal calcarenites equivalent to part of the Callaway Formation.

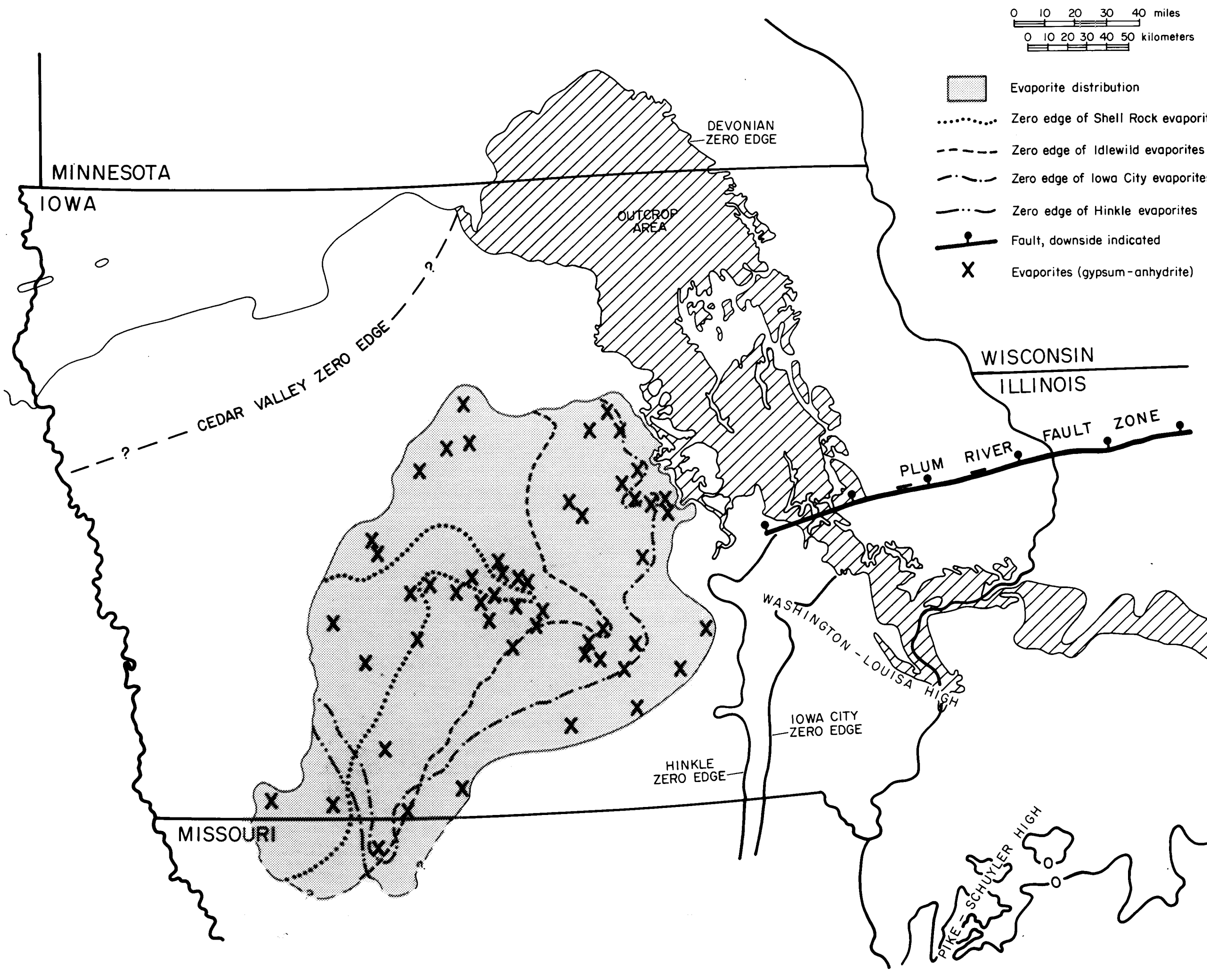


Figure 5. Evaporite distribution map of the Cedar Valley Group and the zero edges of the Hinkle and Iowa City members (from Witzke et al., 1988).

Conodonts from the "*bellula* zone" span parts of the Lower and Upper *hermanni* subzones (Witzke et al., 1988). The lower Rapid ("*bellula* zone") contains a diverse brachiopod-dominated fauna which is described in detail by Stainbrook (1938a-1943b), Witzke et al. (1985), and Day (this guidebook). The upper part of the middle Rapid, by contrast, is an abundantly fossiliferous calcilutite to calcarenite containing conspicuous coralline biostromes over much of the geographic extent of the member. Conodonts of the *subterminus* Fauna, a probable equivalent of the *disparilis* Zone, first occur within this coralline interval (Witzke et al., 1985). Conodonts from the upper Rapid ("*waterlooensis* zone") are assigned to the Lower *subterminus* Fauna (Witzke et al., 1985). The upper Rapid is characterized by crinoidal and bryozoan-rich calcilutites and calcarenites. A relatively diverse brachiopod fauna is present and is described in detail by Stainbrook (1938a-1943b), and Day (this guidebook). Articulated specimens of camerate, inadunate, and flexible crinoids, blastoids, rhombiferans (*Strobilocystites*), starfish, edrioasteroids, and echinoids are known (Calhoun, 1983; Strimple, 1970).

Bassett Member. The Bassett Member (Fig. 3) is dominated by slightly argillaceous to argillaceous dolomite, commonly vuggy, and containing scattered to abundant fossil molds. Limestones and dolomitic limestones generally increase in abundance throughout the member southward in the Iowa outcrop belt. Chert nodules occur locally, generally in the upper half. Stylolites and hardgrounds are present, especially in the lower half of the member. The basal Bassett Member is silty, sandy, and/or conglomeratic in areas where it overlies Ordovician strata.

The Bassett Member disconformably overlies the Wapsipinicon Group throughout most of the outcrop belt, but overlaps the Wapsipinicon edge to the west in the subsurface to overstep the eroded surface developed on Upper Ordovician strata. The member locally overlies beveled Silurian rocks along the trend of the Hardin-Bremer High (Fig. 4), where its basal unit is coralline (Dorheim and Koch, 1962). The Bassett is overlain conformably by the Chickasaw Shale in the northern outcrop belt, where it ranges in thickness from 19 to 25 m. The Bassett is overlain conformably by the Eagle Center Member to the south where it ranges in thickness from 15 to 25 m. The Chickasaw Shale and Eagle Center members are not recognized west of the outcrop belt in the subsurface of north-central and central Iowa; the Bassett averages 30 m in thickness and is conformably overlain by the Hinkle Member in those areas.

The Bassett Member is dominated by dense, sparsely fossiliferous calcilutite and coralline to brachiopod-rich calcarenites near its southern limit. It interfingers with characteristic lithologies of the Solon and lower to middle Rapid members in that area, where it locally overlies the Solon Member and is overlain by upper Rapid strata. Conodonts from the lower part of the Bassett include *Icriodus brevis*, *I. latericrescens latericrescens*, *Polygnathus linguiformis linguiformis* (gamma and epsilon morphotypes), *P. ovatinodosus*, *P. alveoliposticus*, *P. ansatus*, *P. varcus*, *P. xylus xylus*, and others (Klug, 1982b; Klapper and Barrick, 1983; Witzke et al., 1988; Rogers, 1990). This fauna indicates assignment to the Middle *varcus* Subzone, and suggests correlation with most or all of the Solon Member to the south. The lower unit contains an abundant brachiopod fauna, typically atrypid-dominated (*Independatrypa* and *Spinatrypa*). Conodonts of the middle and upper intervals of the Bassett Member are not zonally significant but include *I. brevis*, *I. latericrescens latericrescens*, *P. xylus xylus*, and *P. ovatinodosus* (middle unit); stratigraphic position suggests correlation with the lower and middle parts of the Rapid Member. The middle part of the Bassett is typified by sparsely fossiliferous burrowed calcilutite fabrics, but fossiliferous beds occur within the unit. This unit also includes local packstone beds of *Rensselandia* and sparse corals (pachyporids and favositids) near the southern limits of the member. The upper part contains biostromal beds rich in corals and/or stromatoporoids, variably dominated by favositids, solitary rugosans, *Hexagonaria*, or domal or laminar stromatoporoids, and including *Asterobillingsa* near its southern limit. Glauconitic and phosphatic strata below the Eagle Center Member have produced an interesting fish fauna, as well as conodonts of the basal *subterminus* Fauna (Denison, 1985).

Chickasaw Shale Member. The Chickasaw Shale Member (Fig. 3) is composed of medium-gray dolomitic shale and argillaceous to shaly dolomite, in part silty. Nonskeletal, sparse to abundant burrow-mottled fabrics dominate, but skeletal material is noted in the lower 1 to 1.8 m at most localities (bryozoans, *Neatrypa*, and other brachiopods). The Chickasaw Shale ranges from 5.4 to 6.5 m in thickness. It is replaced to the south by strata of the Eagle Center Member and to the west by argillaceous and silty beds in the upper Bassett Member (Witzke and Bunker, 1984).

Eagle Center Member. The Eagle Center Member (Fig. 3) consists of an interval of argillaceous and generally cherty, laminated dolomite below the Hinkle Member and above the Chickasaw Shale or Bassett Member. The member is dominated by sparsely fossiliferous to unfossiliferous burrowed argillaceous dolomite and contains prominent chert nodules and bands in the lower one-half to seven-eighths. Faint to prominent laminations, in part disrupted by scattered burrow mottles, characterize much of the member at most sections; some laminations are pyritic (Anderson and Garvin, 1984). Thin dolomitized or silicified fossiliferous calcilutite and calcarenite beds are interspersed locally within the generally unfossiliferous sequence. The Eagle Center is not dolomitized to the southeast of the type area, where it is dominated by sparsely fossiliferous to unfossiliferous, burrowed, cherty, argillaceous calcilutite, in part laminated, and contains thin skeletal calcarenite beds. Upward it becomes dominantly finely calcarenitic. Upper Eagle Center strata, primarily in areas where the member overlies the Chickasaw Shale, contain stromatoporoids or corals and are locally biostromal. The Eagle Center Member ranges in thickness from 8 to 11 m where it overlies the Bassett Member, and is 1.4 to 4.2 m thick where it overlies the Chickasaw Shale.

Conodonts from the Eagle Center Member (*Icriodus subterminus* and *Polygnathus xylus xylus*) are assigned to the Lower *subterminus* Fauna (Witzke et al., 1988; Rogers,1990). Macrofauna is sparse in the member, but scattered fish debris (placoderm and shark) is noted in the laminated dolomites. Thin fossiliferous beds within the laminated sequence have yielded brachiopods (*Neatrypa waterlooensis*, *Orthospirifer*, *Cranaena*, and "*Cupularostrum*"), bryozoans, and crinoid debris (Anderson and Garvin, 1984). Upper strata are locally biostromal, primarily in the northern sections, and have yielded corals (*Hexagonaria*, solitary rugosans, and favositids), domal stromatoporoids, brachiopods, crinoid debris, and rostroconchs. The fauna and stratigraphic position indicates correlation of the Eagle Center with upper Rapid strata.

Hinkle Member. The Hinkle Member (Fig. 3) is the uppermost member of the Little Cedar Formation in northern and central Iowa, where it conformably overlies the Eagle Center or Bassett members and is disconformably overlain by the Coralville Formation. It conformably overlies the upper Rapid Member along its southernmost extent. The Hinkle Member is characterized by dense unfossiliferous "sublithographic" limestone and dolomitic limestone, in part with laminated, pelletal, intraclastic, and "birdseye" fabrics. Similar fabrics are noted at all known sections, but the member is partially to completely dolomitized over most of north-central and central Iowa. Hinkle strata are generally unfossiliferous, but burrows, ostracodes, and sparse brachiopods have been noted locally. The member is commonly fractured to brecciated, and argillaceous beds and minor shale (locally carbonaceous) are present at many sections. Laminated carbonates are petroliferous in part, and desiccation cracks and minor erosional disconformities occur within some Hinkle sequences. Gypsum molds are present locally (e.g., Klug, 1982b, p. 47), and the member includes extensive evaporites (gypsum and anhydrite) in central Iowa (Fig. 5). The Hinkle changes character near its eastern margin where faintly laminated limestones are interbedded locally with thin fossiliferous limestone beds containing brachiopods, echinoderm debris, favositids, and domal stromatoporoids. The Hinkle Member averages about 2.5 m in thickness and is known to vary between 0.4 and 4.1 m. Erosional relief, locally to 1 m, is evident below the Coralville Formation at some localities.

Coralville Formation

In an 1866 lecture at the University of Iowa, the internationally famous geologist Louis Agassiz emphasized the significance of fossil coral accumulations in the Iowa City area. Several months later, abundant corals were encountered in limestone layers during the construction of a mill along the Iowa River west of Iowa City. The State Press (December 19, 1866) gave an account of this and of the subsequent naming of a new town, Coralville, for these coral accumulations. Keyes (1912) proposed the term Coralville for these coral-bearing rocks, and included it as a stratigraphic unit within the Cedar Valley Limestone. Stainbrook (1941a) designated the type section at Conklin Quarry adjacent to the city of Coralville, Johnson County, Iowa. In 1988, Witzke et al. designated the Coralville as a formation within the Cedar Valley Group. The Coralville Formation includes a lower fossiliferous carbonate member with an abundant marine fauna (Cou Falls or Gizzard Creek members) and an upper carbonate-dominated unit with laminated, brecciated, or evaporitic textures and some restricted-marine faunas (Iowa City Member). The Coralville Formation was deposited during a single T-R depositional cycle and is bounded above and below by disconformities or discontinuity surfaces. The formation overlies the Little Cedar Formation at all known localities, and where capped by younger Devonian strata is variably overlain by the Lithograph City, Sweetland Creek, or Lime Creek formations. The Coralville formation varies greatly in thickness across Iowa, reaching a maximum thickness of 20 to 25 m in areas of central and northern Iowa. It is as thin as 3.9 m in parts of southeastern Iowa.

Cou Falls Member. The Cou Falls Member (Fig. 3) is characterized by fossiliferous fine-grained calcarenite (primarily an abraded-grain packstone) with coral and stromatoporoid biostromes through much of the sequence (Kettenbrink, 1973). Thin shaly and dark carbonaceous partings occur in the lower half. The Cou Falls Member sharply overlies a prominent discontinuity surface at the top of the Rapid Member; calcarenites of the Cou Falls infill vertical burrows along this surface which locally penetrate up to 30 cm into upper Rapid strata. The Cou Falls Member is conformably overlain by the Iowa City Member in the type area. The Cou Falls Member encompasses the entire Coralville Formation east of the Iowa City Member edge (Fig. 3), where it contains calcarenites (generally coralline) in the lower part and argillaceous calcilutite to calcarenite in the upper part. The Andalusia Member of the Lithograph City Formation overlies a discontinuity surface at the top of the Cou Falls Member in parts of southeastern Iowa. The Cou Falls Member is replaced to the north and west by the Gizzard Creek Member and locally overlies Gizzard Creek strata in a transitional belt near its northern limits. The Cou Falls disconformably overlies the Hinkle Member of the Little Cedar Formation along the southern margin of that unit. The Cou Falls Member ranges from 5 to 7 m in thickness in the type area, and varies between about 3.5 and 11 m in thickness over its geographic extent.

Conodonts of the Cou Falls Member are sparse, but include *Icriodus subterminus*, *Mehlina gradata*, *Polygnathus angustidiscus* and other undescribed species of *Polygnathus*; these indicate assignment to the Upper *subterminus* Fauna (Witzke et al., 1985; Rogers, 1990). Stainbrook (1941a) and Kettenbrink (1973) subdivided the lower Coralville sequence in Johnson County (Cou Falls Member) into two faunal intervals, the lower "*Cranaena* zone" and the upper "*Idiostroma* beds." The "*Cranaena* zone" contains prominent coralline biostromes dominated by colonial (*Hexagonaria*) and solitary rugosans (Pitrat, 1962), favositids, and massive stromatoporoids. Brachiopods are common in some beds (Day, 1988 & this guidebook). The "*Idiostroma* beds" are characterized by biostromal strata containing branching ("*Idiostroma*") and massive stromatoporoids, colonial (*Hexagonaria*) and solitary rugosans, and favositids. The Cou Falls Member east of the Iowa City edge (Figs. 3, 5) resembles "*Cranaena* zone" strata in the lower part, but includes argillaceous calcilutites and calcarenites in the upper part with brachiopods and crinoid debris, locally with corals, stromatoporoids, or abundant bryozoans (Klug, 1982a; Witzke et al., 1985; Day, 1988 & this guidebook).

Gizzard Creek Member. The Gizzard Creek Member (Fig. 3) is dominated by dolomite, generally medium- to thick-bedded in the lower part and medium- to thin-bedded in the upper part, but dolomitic limestones and calcite-cemented (poikilotopic sparites) dolomites are present. The Gizzard Creek Member is slightly argillaceous in part, and calcite-filled vugs are common. Intraclasts are present locally in some beds. The member contains scattered to abundant fossil molds, locally with calcitic fossils, and displays wackestone (calcilutite) to rare packstone fabrics, in part burrow mottled. The Gizzard Creek Member disconformably overlies the Hinkle Member at all localities, and is conformably overlain by the Iowa City Member at most localities. The Gizzard Creek Member ranges from 3.7 to 7 m in thickness.

Conodonts of the Gizzard Creek Member include *Icriodus subterminus*, *Mehlina gradata*, and *Polygnathus angustidiscus* (Witzke et al., 1988; Rogers, 1990) which are assigned to the Upper *subterminus* Fauna. Faunas of the Gizzard Creek are generally of low diversity and are characterized by sparse to abundant crinoid debris and brachiopods (*Independatrypa*, *Athyris*, and rare *Tecnocyrtina*; Day, 1988 & this guidebook). Rare gastropods and bryozoans have been noted, and branching stromatoporoids and favositids are present locally near the southern limits of the member in the outcrop belt.

Iowa City Member. The Iowa City Member (Fig. 3) is characterized by a diverse assemblage of lithologies that commonly share significant lateral facies variations over short distances. The member in the type area of central Johnson County includes the following lithologies: 1) laminated and pelleted calcilutites, commonly "sublithographic" with "birdseye" voids and stylolites; 2) pelleted calcilutites with scattered to abundant corals and/or stromatoporoids; 3) intraclastic, brecciated, or oncolitic limestones; and 4) some thin shales, in part carbonaceous (Kettenbrink, 1973; Witzke, 1984). Mudcracks and vadose pisoliths are noted in some beds, and erosional surfaces occur locally within the sequence (Witzke, 1984).

The Iowa City Member in the northern outcrop belt and in the subsurface of central Iowa is characterized by sedimentary fabrics similar to those of the type area, but includes dolomites and dolomitic limestones. There is a general increase in the relative abundance of shale, with shaly intervals locally up to 2 m thick, breccia, and intraclastic strata in this area, and some beds are locally sandy. Crystallotopic molds after sulfate evaporites have been identified locally. The thickest development of evaporites (gypsum and anhydrite) in the Cedar Valley Group occurs within the Iowa City Member of central Iowa. The Iowa City Member in the type area is disconformably overlain by the State Quarry Member of the Lithograph City Formation or by the Lime Creek Formation. The member is disconformably overlain by the Osage Springs Member of the Lithograph City Formation across northern and central Iowa. The Iowa City Member ranges from 0 to 8 m in thickness in the type area, and from 8 to 17 m across northern and central Iowa. The Iowa City Member is absent 12 km to the southeast of the type locality, where the entire Coralville Formation is represented by fossiliferous calcarenites of the Cou Falls Member. The edge of the Iowa City Member trends south-southwest from the type area (Fig. 5), and the member is absent in southeastern Iowa and adjacent parts of northeastern Missouri and western Illinois. Conodonts have not been recovered from the Iowa City Member. Laminated and "birdseye"-bearing strata are sparsely fossiliferous in part (stromatolites, calcareous algae, foraminifers, ostracodes and gastropods), and some calcilutites are burrow mottled.

Problems relating to the Coralville-Lithograph City contact

Fossiliferous calcilutites and some calcarenites interbed in the upper Iowa City Member sequence and contain low-diversity macrofaunas generally dominated by favositid corals and/or branching stromatoporoids (locally biostromal). A biostromal interval in the middle to upper part of the member ("*Amphipora* bed" of Kettenbrink, 1973) contains abundant branching stromatoporoids in the Johnson County type area, and this interval is presumed to correlate with stromatoporoid-rich strata to the north in the Garrison Quarry (Benton County, Iowa; STOP 1) area (Witzke et al., 1988). The recent recovery of the conodont *Pandorinellina insita* from laterally equivalent strata to "*Amphipora*" bearing beds at Garrison Quarry have tended to obfuscate the contact relationships between the Iowa City Member and the overlying Lithograph City Formation as originally defined by Bunker et al. (1986) and Witzke et al. (1988). At Garrison Quarry (STOP 1) *P. insita* bearing strata can be observed overlying and cross-cutting lower and middle Coralville Formation strata (Gizzard Creek and Iowa City members) which is similar to stratigraphic relationships observed between the State Quarry Member of the Lithograph City Formation and the underlying Coralville and Little Cedar formations in the Coralville Lake area north of Iowa City.

Watson (1974) proposed that the State Quarry Member was laterally equivalent to strata now included in the upper Iowa City Member. However, this proposal has not been supported by any physical evidence identified in subsequent studies. In particular, the locality along the west shoreline of Coralville Lake where Watson (1974) described facies relationships between the Coralville and State Quarry consists of a minor erosional re-entrant that cuts across critical sections which contain the calcilutite beds of both the Coralville and State Quarry. Re-examination of the above described calcilutite beds within the "upper Coralville" indicates that these beds actually are contained within the upper part of the Cou Falls Member, and exhibit a lateral facies relationship with the *Idiostroma* beds. These calcilutite beds contain a brachiopod fauna that is distinctly associated with the Coralville Formation. Similarly, brachiopod faunas collected from the calcilutite beds of the State Quarry in this area are distinctively associated with the Lithograph City Formation (Jed Day, pers. comm., 1991) and not with the Coralville Formation.

Bunker et al. (1986) noted problems with the stratigraphic relationships between the Coralville and Lithograph City formations at Yokum Quarry in northwestern Blackhawk County, Iowa. In north-central Iowa, the basal contact of the Lithograph City Formation is primarily based upon the upward change in character from laminated lithographic and intraclastic unfossiliferous limestones from the underlying Coralville cycle below to fossiliferous limestones above. The overlying fossiliferous interval contains the conodont *Pandorinellina insita* and a brachiopod fauna characteristic of the Lithograph City Formation to the north. However, as noted by Bunker et al. (1986), the recovery of *P. insita* from the underlying laminated lithographic and intraclastic limestones at Yokum Quarry could suggest that the base of the Lithograph City should be moved downward. The inclusion of laminated lithographic and intraclastic limestones within the basal Osage Springs Member, however, is generally inconsistent with its character to the north and west, where it is a fossiliferous unit. Alternatively, the inclusion of these limestones with the Coralville Formation also poses a potential problem, since the first occurrence of *P. insita* would then fall within the upper regressive portion of the Coralville, instead of within the basal transgressive portion (Osage Springs-Andalusia) of the Lithograph City Formation as noted elsewhere in Iowa (ibid., p. 34).

The *Amphipora* beds at Garrison Quarry appear to equate with the initial Lithograph City marine transgression, as indicated by significant lateral incision of underlying Coralville units and by its contained faunas. By constrast, the *Amphipora* beds in Johnson County do not display lateral transition into open-marine facies, and lack faunas characteristic of the Lithograph City Formation (conodonts, brachiopods, etc.). As such, the *Amphipora* beds of the type Iowa City Member are interpreted to mark a minor transgressive event within the overall regressive phase of upper Coralville deposition. The significant Lithograph City marine transgression, initially marked by deposition of the State Quarry Member, in Johnson County, shows no obvious relationship to the *Amphipora* beds. Nevertheless, the absence of demonstrated litho- or biostratigraphic relationships between the *Amphipora* beds of the Iowa City Member and the State Quarry provides only negative evidence. The possibility that the *Amphipora* beds in Johnson County represent some early stage of Lithograph City transgression, correlative with similar facies at Garrison Quarry, cannot, as yet, be completely ruled out. Of special note is the fact, birdseye-bearing limestones in the lower type Iowa City Member are locally truncated and capped by an atrypid-bearing hardground surface and large stromatopotoid colonies below *Amphipora* bearing strata (Presidents House Quarry, Witzke, 1984). The vertical sequence resembles, in a gross sense, that seen above the Coralville Formation at Garrison Quarry.

The basal Lithograph City Formation across northern Iowa is marked by an open-marine carbonate, the Osage Springs Member, which is greater than 3 m thick. At Garrison Quarry, however, the basal marine interval of the interpreted Lithograph City Formation is locally less than 1 m thick, suggesting that this interval may not represent the Osage Springs transgression. Is Unit 27 (see STOP 1) at Garrison Quarry really the Osage Springs correlate? Does the basal *insita*-bearing interval at Garrison precede the Osage Springs transgression to the north? If so, the base of the Lithograph City Formation at Garrison Quarry (and presumbly correlative strata in an offshore direction, i.e. the State Quarry) would then correlate with strata currently placed in the upper Iowa City Member strata in northern Iowa. Does this mean that the Lithograph city transgression was step-wise, with the earliest transgressive phases not represented by marine incursion in the northern sections? It remains to be seen if there are any regional facies relationships between uppermost Coralville and lowermost Lithograph City strata. In general, the Coralville is disconformably overlain by Lithograph City strata at most Iowa localities, and the two formations are readily distinguishable by their stratigraphic position, depositional facies, and faunas. Nevertheless, if the lower Lithograph City transgression was a step-wise event, regional stratigraphic relations may need some minor revision. Further study is encouraged.

Lithograph City Formation

The Lithograph City Formation was proposed (Bunker et al., 1986; Witzke et al., 1988) for the interval lying disconformably between the Coralville Formation below and the Shell Rock Formation or Sweetland Creek Shale above. The type locality of the formation was designated in the old quarry area adjacent to the former town of Lithograph City, Floyd County, Iowa, where high quality stone for lithographic engraving was quarried in the early 1900s (see discussion and map in Bunker et al., 1986). The Lithograph City Formation in northern Iowa includes limestone, shale, and dolomite, variably fossiliferous, laminated, or brecciated; evaporites are present in central Iowa. The formation is dominated by fossiliferous limestone, dolomite, and shale in southeastern Iowa. Three members of the formation are recognized in northern Iowa (Osage Springs, Thunder Woman Shale, and Idlewild; Fig. 3). Two distinctive facies south of the northern outcrop belt are assigned member status within the Lithograph City Formation (Fig. 3; State Quarry Member in eastern Iowa and the Andalusia Member in southeastern Iowa and adjacent areas of northeastern Missouri and western Illinois). Where capped by younger Devonian strata, the formation ranges from about 20 to 36 m in thickness in northern and central Iowa. It is thinner to the southeast where it ranges from 0 to 12 m in thickness.

Significance of the insita Fauna. Klapper and Barrick (1978) recognized the difficulty of inferring habitat from observed distributions of conodonts in sedimentary rocks. However, they note that certain species characterize near-shore environments (e.g. *Icriodus*) while other species consistently occur in relative deeper offshore positions (e.g. *Palmatolepis* & *Ancryodella*). An excellent example of the contrast between the two biofacies is represented by the development of the *insita* biofacies, which is characterized by an improvished fauna of *Pandorinellina insita* and *Icriodus* sp. (Johnson & Sandberg, 1977). The *insita* Fauna as originally defined by Klapper et al. (1971) consisted of the interval of strata dominated by *P. insita* below strata containing the lowest occurrence of *Ancyrodella rotundiloba*. The lower limit of the *insita* Fauna has biostratigraphic significance, but its upper limit is not well defined; noted to range as high as the Middle *asymmetrica* Zone (Montagne Noire Zone 5, Klapper, 1988) in the Waterways Formation of Alberta (Uyeno, 1974). Strata with the first occurrence of *Skeletognathus norrisi* (Uyeno, 1967) occupy a prominent stratigraphic position above the *disparilis* Zone and below the first occurrence of *Ancyrodella rotundiloba* (Johnson, 1978). This interval has commonly been correlated with the Lowermost *asymmetrica* Zone, originally defined on the range of *Mesotaxis asymmetrica* below the lowest occurrence of *A. rotundiloba* early form (Ziegler, 1971). Klapper and Johnson (1990) redefined this interval, terming it the *norrisi* Zone based upon the lowest occurrence of *S. norrisi*. The oldest part of the *insita* Fauna, characterized by an association of *Pandorinellina insita* and *Skeletognathus norris,i* is assigned to the *norrisi* Zone.

Osage Springs Member. The Osage Springs Member (Fig. 3) is characterized by fossiliferous dolomite and dolomitic limestone, in part slightly argillaceous, in the type area. Calcite-filled vugs and stylolites are common, and poikilotopic calcite cements are present locally in the upper part of the member. Thin intervals containing faintly laminated to intraclastic fabrics have been noted at some localities. The Osage Springs Member in its type area of north-central Iowa is similar both in thickness and lithology to the Gizzard Creek Member of the Coralville Formation, but is distinguishable by its higher stratigraphic position and differing fauna. The Osage Springs Member becomes limestone-dominated (skeletal calcilutite and calcarenite) southward in the northern Iowa outcrop belt, and stromatoporoids (locally biostromal) also become increasingly common in that direction. Fossiliferous and locally oolitic limestones and dolomites have been noted in central Iowa (Klug, 1982b). The member is conformably overlain by laminated carbonates of the Idlewild Member in the northern outcrop belt, and is conformably overlain by the Thunder Woman Shale in the southern outcrop belt and in the subsurface of central Iowa. The Osage Springs Member varies from 3.4 to 7.5 m in thickness.

The conodont *Pandorinellina insita* first occurs in north-central Iowa in the basal Osage Springs Member (Bunker et al., 1986). Based upon the first occurrence of *P. insita* within the basal Osage Springs Member, the Osage Springs has been correlated with the *norrisi* Zone (Witzke et al., 1985; Bunker et al., 1986; Witzke et al., 1988).

Macrofauna of the Osage Springs Member is dominated by brachiopods in northern outcrops; *Allanella, Athyris, Independatrypa*, and *Strophodonta* are characteristic (Day, 1988). Stromatoporoids become abundant to the south and include both massive and branching forms. Echinoderm debris is present in all sections, and bryozoans, gastropods, corals, and burrows have been noted locally.

Thunder Woman Shale Member. The Thunder Woman Shale Member (Fig. 3) is characterized by light to medium gray, slightly dolomitic and silty shale; argillaceous dolomite is present locally, in part laminated and with crystallotopic gypsum molds. Shelly fossils are absent in the member, but horizontal and subhorizontal burrow mottles are common in the upper half. Conodont fragments and fish debris have been noted in the subsurface of north-central Iowa (Klug, 1982b). The Thunder Woman Shale is present in the southern part of the northern outcrop belt of the Lithograph City Formation, and extends into the subsurface of central Iowa (Bunker et al., 1986). It is erosionally truncated to the south within the Devonian outcrop of eastern Iowa. The member is replaced northward in the outcrop belt of northernmost Iowa and adjacent Minnesota by carbonate dominated strata of the lower Idlewild Member (Fig. 3). The Thunder Woman Shale ranges from 3 to 6 m in thickness.

Idlewild Member. The Idlewild Member (Fig. 3) is characterized by an interbedded sequence of contrasting lithologic groupings: 1) laminated and pelleted lithographic and "sublithographic" limestones and their dolomitized equivalents, in part with mudcracks, "birdseye," or evaporite molds; 2) non-laminated dolomite and limestone, in part "sublithographic," pelleted, oncolitic, intraclastic, brecciated, and/or sandy, and locally containing mudcracks and "birdseye"; 3) calcareous shale, in part brecciated to intraclastic; and 4) fossiliferous dolomite and limestone (calcilutite and minor calcarenite), with scattered to abundant brachiopods and/or stromatoporoids (locally biostromal; see Smith & Stock this guidebook). Lithologic groupings 1 and 2 dominate the sequence at most localities, but group 4 lithologies are subequal in importance at some sections. Fossiliferous carbonates that interbed with the sequence cannot generally be correlated from section to section, although an interval of fossiliferous strata in the middle part of the member occurs at a similar stratigraphic position in most sections (lower "Unit D" of Witzke and Bunker, 1984, 1985) and probably correlates regionally. The Idlewild Member contains gypsum and anhydrite in the subsurface of central Iowa (Fig. 5), primarily in the lower part of the member. The member is replaced by fossiliferous carbonates of the middle and upper Andalusia Member in southeastern Iowa. Where capped by the Shell Rock Formation, the Idlewild Member ranges from 16 to 24 m in thickness.

Conodonts from fossiliferous beds in the Idlewild Member include *Pandorinellina insita* and *Polygnathus angustidiscus*; these are assigned to the *insita* Fauna, however, regional relations suggest that the member spans a portion of the range of the *norrisi* and Lower *asymmetricus* zones. Lithologic groupings 1 and 2 commonly contain ostracodes and are burrowed in part; stromatolites and gastropods have been noted locally. Fossiliferous beds in the member contain brachiopods (Day, 1988 & this guidebook); *Allanella* and *Athyris* typically dominate. Echinoderm debris is common in some beds, and bryozoans, gastropods, and ostracodes also occur. Stromatoporoids are abundant in some beds, and locally form biostromes (domal or branching forms variably dominate). Favositids are present locally.

State Quarry Member. The State Quarry Member (Fig. 3) is restricted to Johnson County, Iowa, where it occupies broad channels (1 to 1.5 km wide) incised into the Coralville and Little Cedar formations (to as low as the middle Rapid Member). It is covered by Quaternary sediments at most localities, but it is overlain locally by the Lime Creek Formation ("North Liberty beds"). The State Quarry Member is characterized by fossiliferous calcarenites and calcilutites (Watson, 1974). Skeletal calcarenites (packstones and abraded grainstones) predominate at most localities, and are crossbedded in part. These are dominated by echinoderm, brachiopod, and/or stromatoporoid grains. Intraclastic and pelletal calcarenites also occur. Skeletal calcilutites are present near the channel margins. Fish bone lags are noted locally at or near the base of the member. The State Quarry Member reaches thicknesses of up to 12 m.

The conodont fauna of the State Quarry Member includes *Pandorinellina insita, Polygnathus angustidiscus, Skeletognathus norrisi,* and *Icriodus subterminus* (Watson, 1974; Witzke et al., 1985; Kralick this guidebook); it is assigned to the *norrisi* Zone. Other conodonts are also present, many apparently reworked from Rapid and lower Coralville strata. The State Quarry Member contains a macrofauna characterized by abundant echinoderm debris, brachiopods, and stromatoporoids. A variety of brachiopods occur (Day, 1988 & this guidebook). Branching and massive stromatoporoids, solitary rugosans, favositids, auloporids, gastropods, nautiloids, spirorbids, ostracodes, trilobites, calcareous algae and foraminifera, and fish debris (placoderms and dipnoans) have been noted (Watson, 1974).

Andalusia Member. The Andalusia Member (Fig. 3) is characterized by argillaceous and fossiliferous dolomitic limestone, limestone, and dolomite with fossiliferous calcareous shales in the lower part. Dolomite content generally increases upward in the section. Coral and stromatoporoid biostromes are present in the upper two-third's of the member in its type area. Hardground and discontinuity surfaces, in part auloporid encrusted, occur within the Andalusia sequence in the lower and upper parts. The member overlies a discontinuity surface at the top of the Coralville Formation, and where capped by younger Devonian strata, is disconformably overlain by the Sweetland Creek Shale. The Andalusia Member is replaced by strata of the Osage Springs and Idlewild members to the northwest along the outcrop belt, and in subsurface sections it locally interfingers up depositional slope with the State Quarry Member in the basal part. The Andalusia Member, where capped by the Sweetland Creek Shale, ranges from about 6 to 12 m in thickness.

Conodonts of the *insita* Fauna range through most of the Andalusia Member and include *Pandorinellina insita, Mehlina gradata, Icriodus subterminus,* and *Polygnathus* sp. (Witzke et al., 1985; Day, this guidebook). Uppermost strata of the member have yielded *Ancyrodella rugosa, A. africana, A. alata* (late form), *Mesotaxis asymmetricus, I. subterminus,* and *M. gradata*; these forms indicate assignment to the upper part of the Lower *asymmetricus* Zone (ibid.; also correlated with M.N. Zone 3, Klapper, 1988; Johnson and Klapper, 1992). Brachiopods of the Andalusia Member have been described by Day (1988 & this guidebook). Echinoderm debris is common to abundant, and bryozoans, bivalves, gastropods, rostroconchs, nautiloids, and fish debris are noted in some beds. Biostromal units in the upper Andalusia Member are variably dominated by solitary rugosans (*Tabulophyllum* sp.) or massive stromatoporoids.

Shell Rock Formation

Belanski (1927) named the "Shellrock stage" (formation) for a limestone-dominated interval exposed along the Shell Rock River in northern Iowa, and subdivided it into three "substages" (members), in ascending order, the Mason City, Rock Grove, and Nora. The Shell Rock Formation is now included in the upper Cedar Valley Group (Witzke et al., 1988; Fig. 3). A comprehensive summary of the stratigraphy of the formation in the type area is given by Koch (1970) and Witzke et al. (1988). The Shell Rock Formation is characterized by fossiliferous carbonates with some shale in the type area, but incorporates laminated, "birdseye"-bearing, brecciated, and intraclastic facies in the western outcrop and subsurface. Where capped by younger Devonian strata, the Shell Rock Formation ranges from about 17 to 24 m in thickness over its known geographic extent in northern and central Iowa. It disconformably overlies the Idlewild Member, and erosional relief has been noted locally. The eroded upper surface of the formation is buried by the Lime Creek Formation.

Conodonts of the Shell Rock Formation, which include *Ancyrodella gigas, Polygnathus asymmetricus,* and others (Anderson, 1964, 1966; Witzke et al., 1988), indicate correlation with the Middle and/or Upper *asymmetricus* zones. Brachiopod faunas of the Shell

Rock are correlated with Faunal Interval 30 (= Middle *asymmetricus* Zone) of the western United States by Day (1988). Brachiopods and echinoderm debris are present in all members, and articulated specimens of crinoids, rhombiferans, edrioasteroids, and disarticulated echinoids are known from the Mason City Member (Belanski, 1928; Koch and Strimple, 1968; Strimple, 1970). Molluscs are common locally and include bivalves, gastropods, nautiloids, and scaphopods. Biostromal beds in the Mason City and Nora members are dominated by stromatoporoids, and massive (tabular to subspherical) and branching forms are present (see taxonomic studies by Stock, 1982, 1984a, b). Corals (solitary and colonial rugosans, and tabulates) occur in some beds. Additional fossils include ostracodes, spirorbids, conularids, calcispheres, calcareous algae, charophytes, and fish debris (Koch, 1970).

"North Liberty Beds"

Approximately 1-1/2 miles to the northeast of North Liberty in a tributary (NE 1/4 sec. 7 to NW 1/4 sec. 8, T80N R6W) to the Iowa River there are a series of discontinuous exposures of a fine-grained, greenish-blue, noncalcareous shale. Discontinuous brown shales occur locally near the base, but exposures are poor and relationships to the green shale are unclear. Abundant spore carps are noted in these beds in well cuttings to the west. The "North Liberty beds" range in thickness from 0 to 75 feet, and variably overlie Coralville, State Quarry, and Andalusia (?) strata within the area. An argillaceous dolomitic unit occurs in the upper part in wells around North Liberty, and is tentatively assigned to the Cerro Gordo Member of the Lime Creek Formation (Cerro Gordo strata are exposed 16 mi to the west at Middle Amana). The recovery of *Palmatolepis semichatovae* (Müller & Müller, 1957, p. 1101-1102, Pl. 142, fig. 9; see synonymy in Klapper & Lane, 1988; Day, 1990) from the "North Liberty beds" provides a basis for correlation with the Juniper Hill to lower Cerro Gordo members of the Lime Creek Formation, north-central Iowa (Day, 1990). The lowest occurrence of *P. semichatovae* defines the base of Frasnian Zone 5 in the Alberta conodont sequence (Klapper & Lane, 1988), and suggests assignment of the "North Liberty beds" to this zone. Directly underlying the "North Liberty beds" is an undefined "dark yellow-brownish, dolomitic, fine crystalline thin-bedded limestone" (Müller & Müller, 1957; p. 1075). Müller and Müller (1957) considered the possibility that this dolomitic unit could represent "basal State Quarry limestone," or uppermost Cedar Valley, as suggested by Youngquist (1947). Several samples were dissolved in acetic acid for conodonts by Müller and Müller, but with no success. This dolomitic unit is re-evaluated in view of the new stratigraphic framework. In traversing up the same tributary from its opening at Coralville Lake, a normal stratigraphic succession from basal Cou Falls through the Iowa City members is encountered, with occasional outcrops of State Quarry overlying various units of the Coralville. Along the upper reaches of the tributary is an exposure of this dolomitic unit in apparent vertical sequence above the Iowa City Member (same locality as the overlying "North Liberty beds" noted above). Based upon lithostratigraphic relationships as defined by Witzke et al. (1988), this unit is tentatively assigned to the Andalusia Member of the Lithograph City Formation. Approximately 3 kg of this unit were processed for conodonts, with *Icriodus subterminus* the only element recovered at this time. Of interest, uppermost State Quarry strata near the southern margin of the type State Quarry channel include dolomitic lithologies, perhaps suggesting that the State Quarry channel is gradationally capped by Andalusia dolomitic strata. Dolomitic strata apparently overstep the State Quarry margins to lie directly on upper Coralville strata (at North Liberty). An examination of the combined geologic and structure map of the Coralville Lake area (Plocher and Bunker, 1989, fig. 6) shows that the "North Liberty beds" and Lithograph City Formation are primarily contained within a northeast-southwest trending syncline developed along the southeastern flank of the Twin View Heights Anticline. Preservation of the State Quarry Limestone is fortuitous because it is preserved in a paleotopographic low cut into the Coralville and Little Cedar formations, and because of its structural preservation within a local syncline.

DEPOSITIONAL CYCLES

The Wapsipinicon and Cedar Valley groups display stratigraphic and biogeographic relations that are critical for understanding paleogeography and depositional systems in the Devonian seaways of the central North American midcontinent region. The first marine transgression into the area was marked by deposition of Otis and Spillville strata during the Late Eifelian. This transgression also apparently breached the Transcontinental Arch, establishing faunal communication between eastern and western regions of North America across shallow cratonic facies in the Iowa area. Subsequent deposition of the Pinicon Ridge Formation marked a regional expansion of the seaway, but the expanded seaway apparently displayed restricted circulation patterns that excluded normal-marine benthos across the region. Antiestuarine circulation (Witzke, 1987) with circulatory restrictions to the east and northwest may have promoted the development of hypersalinity in the region, and extensive shallow-water and/or supratidal evaporites were deposited.

Midcontinent Carbonate Shelf

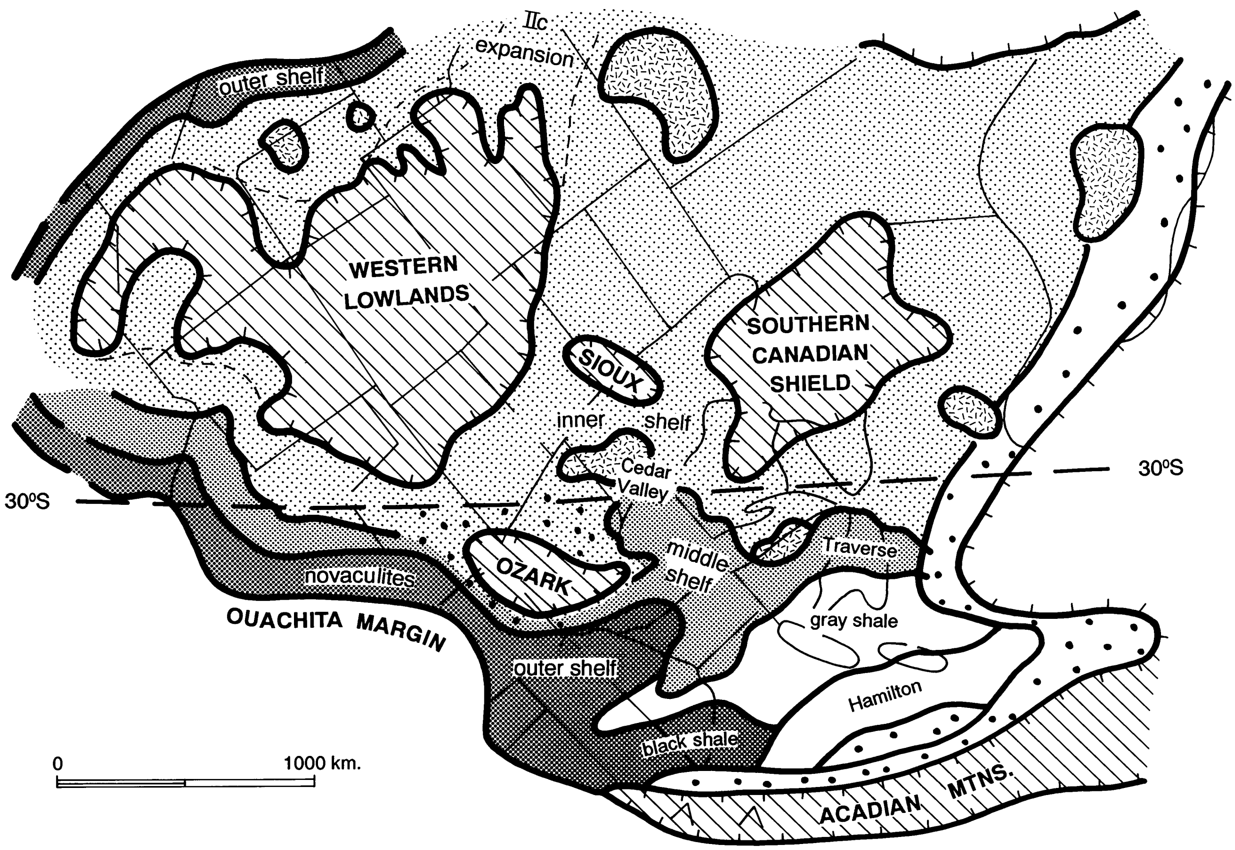
Subsequent deposition of the Cedar Valley Group was marked by significant expansion of the seaway, and open-marine facies spread across most of Iowa. Stratigraphic relationships within the Cedar Valley Group show a marked thinning of all formations into southeastern Iowa (Fig. 3). Although stratigraphic thinning is commonly associated with shallowing depositional trends in many basins, facies in southeastern Iowa are consistently deeper-water and more open-marine than those to the north and west. In fact, the shallower-water facies, including evaporites (Fig. 5), occupy the central region of the Iowa Basin (Fig. 2). Therefore, the Iowa Basin did not develop as a bathymetric basin, but represents an intershelf basin in which shallow-water and mudflat sedimentation kept pace with increased subsidence during deposition of the Cedar Valley Group (and Lime Creek Formation as well, Witzke, 1987). Tidal-flat facies did not prograde out of the intershelf basin area during regressive episodes, but terminated at an intracratonic shelf margin, which is preserved in southeastern Iowa and adjacent northeastern Missouri (Fig. 5, Hinkle and Iowa City edges). This shelf margin bounded an area to the west termed the "Midcontinent Shelf" (Fig. 6) by Slingerland (1986), who numerically modelled tidal effects in the Late Devonian epicontinental seaway. Tidal influence is evident by extensive intertidal and supratidal mudflat facies in the Midcontinent Carbonate Shelf area (i.e. the Iowa Basin area), and by tidal-channel facies (e.g. the State Quarry Member) along the intracratonic shelf margin.

The progressive deepening of depositional facies of the Cedar Valley Limestone to the southeast may relate to subsidence in the Illinois Basin, in a manner similar to that described for succeeding deposition of the Lime Creek Formation (Witzke, 1987). Sedimentation patterns in the Illinois Basin throughout the Devonian indicate consistently deeper-water depositional conditions than that interpreted for coeval strata in northern and central Iowa. However, a linear deepening trend between the Midcontinent Carbonate Shelf area and the deep Illinois Basin is not as evident during Cedar Valley deposition, primarily because of an intervening structural high in central Illinois, the Sangamon Arch (Whiting and Stevenson, 1965).

Cycle Boundaries

Deposition of the Wapsipinicon and Cedar Valley groups in Iowa was marked by a series of six major T-R depositional cycles (Figs. 3, 7). Each cycle of the Cedar Valley Group is bounded regionally by disconformities and each was terminated by the progradation of mudflat facies. Evaporite deposition generally occurred during the regressive portions of each cycle (Fig. 7). These cycles correspond closely to T-R cycles Ie through IIc of Johnson et al. (1985), and additional subcycles are recognized. T-R cycle IIa of Johnson et al. (1985) is provisionally subdivided into three subcycles in the Iowa area as shown on Figure 6. Additional minor T-R subcycles are interpreted for the following intervals: Kenwood, Spring Grove-Davenport, lower-middle Rapid, upper Rapid, upper Iowa City, middle-upper Idlewild, Mason City-lower Rock Grove, and upper Rock Grove-Nora.

A significant erosional hiatus (Upper *asymmetricus* and most or all of the *A. triangularis* zones) separates the Shell Rock and Lime Creek formations in Iowa (Figs. 3, 7), indicating complete withdrawal of Devonian seas from the Iowa area following Shell Rock deposition. If general southeastward thinning of stratigraphic units and depositional trends observed through most of the Cedar Valley sequence also hold for the Shell Rock Formation, a thin Shell Rock section would be expected to have been deposited in southeastern Iowa (Fig. 3). The apparent absence of Shell Rock strata in this area would be anomalous were it not for the development of a significant regional unconformity following Shell Rock deposition. It is suggested that Shell Rock strata in southeastern Iowa were removed by erosion rather than nondeposition. Lime Creek sediments ("Independence shale") locally infill karstic openings within Middle Devonian carbonates of east-central Iowa, and an episode of pre-Lime Creek erosion and karstification has been interpreted (Bunker et al., 1985).



LATE GIVETIAN - EARLY FRASNIAN

Emergent land	Inner shelf environments: peritidal and shallow subtidal facies (including mudflats, evaporites, breccias, and intraclasts); with thin transgressive marine intervals
Mountains	
Eastern-derived clastics	Middle shelf environments: dominantly subtidal open-marine facies (including skeletal mudstones, wackestones, and packstones; part argillaceous)
Sandy	
Evaporites (gypsum-anhydrite)	Outer shelf environments: starved shale sedimentation; minor thin carbonates; locally phosphatic; novaculites

Figure 6. Paleogeographic map of the Midcontinent Carbonate Shelf area during Cedar Valley deposition.

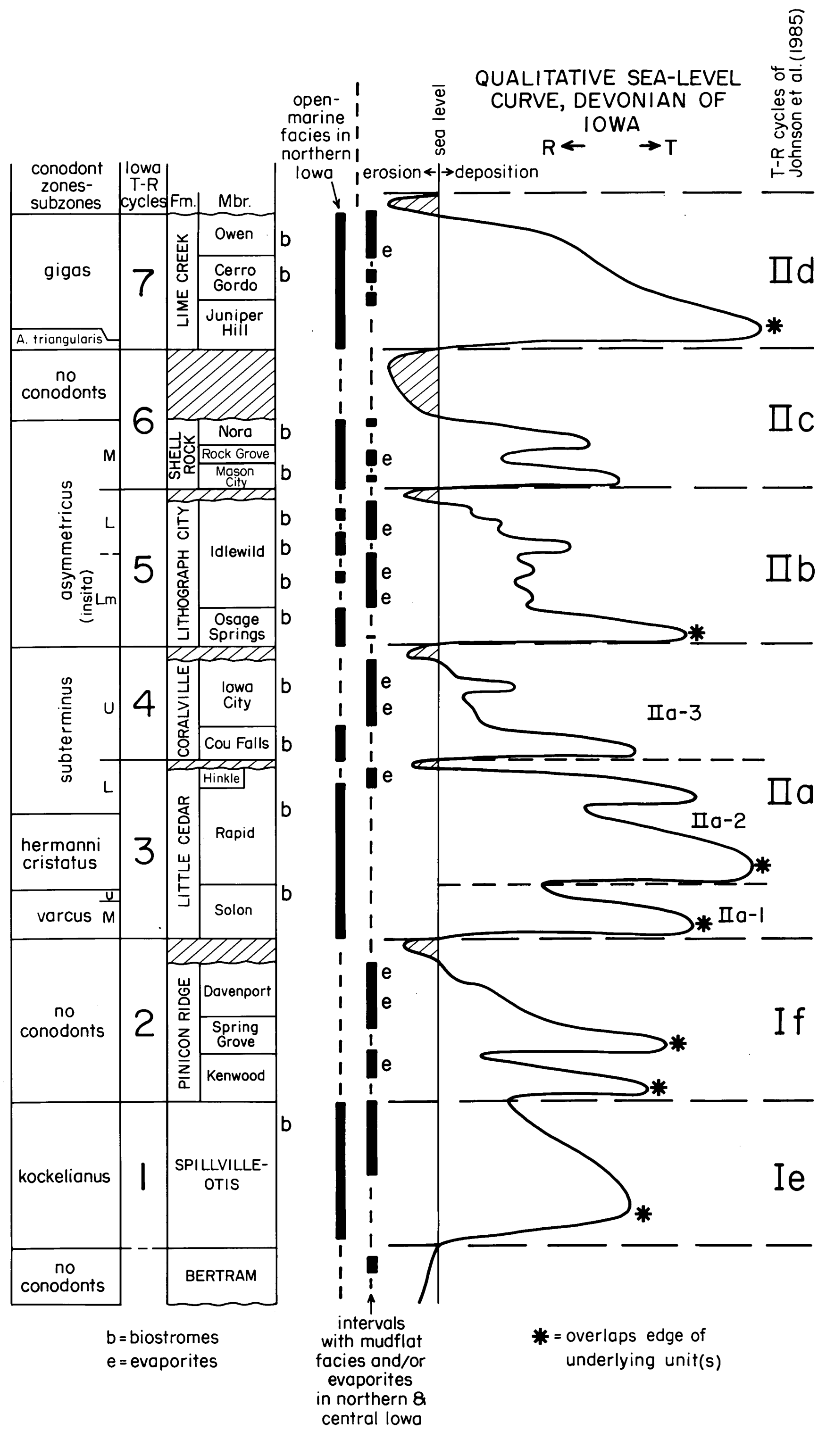


Figure 7. Qualitative sea-level curve for the late Middle and early Upper Devonian rocks of Iowa and their relationship to the T-R cycles of Johnson et al. (1985). (from Witzke et al., 1988).

INTERREGIONAL CORRELATIONS

While the lithostratigraphic framework of the Iowa Cedar Valley Group can be constructed upon the basic tenet of T-R cycles, extrapolation and correlation of these T-R cycles across the Midcontinent Carbonate Shelf area are in need of further study and refinement. A brief summary of proposed relationships between the Cedar Valley Group and strata in central Missouri and Manitoba is contained in Witzke et al. (1988). A lithostratigraphic framework for the Michigan Basin area has been in part developed by Kesling et al. (1974, 1976), and this framework, particularly in western Michigan, is reminiscent of T-R cycles defined in the Iowa Cedar Valley Group. The conodont biostratigraphic framework as defined by Witzke et al. (1988) and summarized in this report provides a potential basis for correlation into the western Michigan portion of the Midcontinent Carbonate Shelf area. Conodont biostratigraphy in the Michigan Basin area has been summarized by Orr (1971) and Bultynck (1976), although conodont ranges and zonal assignments are in need of re-examination.

In 1982, Ziegler and Klapper proposed the *disparilis* Zone, which is characterized by *Klapperina disparilis*, *Klapperina disparata*, and *Klapperina disparalvea*. Additionally, Klapper and Johnson (1990) proposed two subzones within the *disparilis* Zone to coincide with informal lower and upper parts (Ziegler & Klapper, 1982) based on the entry within the zone of *Polygnathus dengleri* (upper part). The recovery of *Klapperina disparalvea* by the authors from the basal exposure of the type Petoskey Formation therefore indicates assignment of the Petoskey to an age no older than the lower *disparilis* Zone. This is in opposition to assignment of the younger Thunder Bay and Whiskey Creek formations to the *varcus* Zone (Orr, 1971; Bultynck, 1976; Gutschick & Sandberg, 1991) and indicates that correlations within a significant portion of the Traverse Group of Michigan needs reassessment. Assuming that the *insita* Fauna of the Lithograph City Formation (as noted by the occurrence of *S. norrisi* within the State Quarry Member, Watson, 1974) correlates with the *norrisi* Zone, then the subjacent *I. subterminus* Fauna in the upper Little Cedar (above the Rapid biostromes) and Coralville formations must correlate with part or all of the *disparili* Zone. However, diagnostic species of the *disparilis* Zone, which developed in an offshore conodont biofacies, have not yet been noted in association with the nearshore *I. subterminus* Fauna of the Iowa portion of the Midcontinent Carbonate Shelf area.

The sequence of T-R cycles in western Michigan is reminiscent of that seen in Iowa, with fossiliferous subtidal marine intervals capped by regressive packages (like the Charlevoix amd parts of the Whiskey Creek) containing sublithographic limestones, oolites, exposure surfaces, and local evaporites. Consistent with occurrences of *disparalis* Zone conodonts in the Petoskey (this study) and *Ancyrodella rotundiloba* in the Jordan River (Bultynck, 1976, loc. 6c), the sequence of T-R cycles in the Traverse Group of western Michigan is tentatively related to the Cedar Valley Group as follows: 1) [upper] Gravel Point-Charlevoix and Little Cedar, 2) Petoskey and Coralville, 3) Whiskey Creek and lower Lithograph City, and 4) Jordan River-Squaw Bay (upper) and upper Lithograph City. Additional litho- and biostratigraphic studies are needed.

SUMMARY

Although some epicontinental sea bottoms apparently were characterized by uninterrupted gently sloping surfaces (ramps), some epicontinental seas, like those in which the Cedar Valley Group were deposited, display linear belts across which significant changes in depositional slope and sedimentary facies are noted. These belts delineate intracratonic shelf margins separating "inner" from "middle" or "outer" shelf environments. Exposures of Cedar Valley strata in eastern Iowa occur along the general transect of such shelf margin environments, with deeper ("middle" shelf) environments to the east and southeast. The basic T-R cycles of the Cedar Valley Group (Witzke et al., 1988) consist of a basal fossiliferous interval which records deposition in open-marine carbonate shelf environments during successive transgressive phases, while laminated, intraclastic, brecciated carbonates and evaporites record deposition in shallow, restricted subtidal and tidal-flat settings during the regressive (progradational) phase. The hierachial order of stratigraphic nomenclature within the Middle Devonian rocks of the Midcontinent Carbonate Shelf region is best developed within the framework of cyclic patterns of deposition. The Wapsipinicon and Cedar Valley groups of the Midcontinent Carbonate Shelf region record repetitive patterns of deposition, which can be observed over large areas of the continental interior and correlated with apparent eustatic sea-level events elsewhere across Euramerica.

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STABLE ISOTOPIC SYSTEMATICS OF THE CORALVILLE T-R CYCLE

by

Orrin W. Plocher, Greg A. Ludvigson, Brian J. Witzke
Iowa Department of Natural Resources
Geological Survey Bureau
Iowa City, Iowa 52242

Luis A. González
Department of Geology
University of Iowa
Iowa City, Iowa 52242

James E. Day
Department of Geography-Geology
Illinois State University
Normal, Illinois 61761-6901

INTRODUCTION

During the past decade, many workers have focused research efforts on Devonian strata in Iowa. Topics have included stratigraphy, biostratigraphy, paleontology, paleomagnetism, diagenesis, and geochemistry. These research results have culminated in a comprehensive understanding of facies architecture and relative sea level changes in these units. These studies provide the basis to undertake a detailed investigation of the stable isotopic systematics of the Coralville Formation.

The Middle Devonian Cedar Valley Group has been subdivided into four formations each representing deposition during a single transgressive-regressive (T-R) sea level change (Witzke et al., 1988; Fig. 1). Regionally, these cycles are capped by regressive peritidal facies, subareal exposure surfaces, or submarine discontinuity surfaces. Studies of depositional facies conclude that the onshore to offshore direction is northwest to the southeast, along the outcrop belt (Witzke et al., 1988; Plocher, 1990).

The Coralville Formation in Johnson County, Iowa, is well suited for isotopic investigations because it is removed from the complexities posed by regional dolomitization and silicification to the northwest, and the cycle is well developed and easily recognized. The Lower Coralville Formation, Cou Falls Member, is interpreted to record subtidal open marine deposition after the initial trangression. Overlying the Cou Falls is the Iowa City Member, which was deposited in peritidal environments punctuated by multiple subaerial exposure surfaces. The interval of interest examined in this paper includes the Cou Falls Member and the Iowa City Member up to and including the first exposure surface (Fig. 2) at the type section of the Cou Falls Member (STOP 3).

THE CORALVILLE FORMATION

The Cou Falls Member of the Coralville Formation at Mid-River Marina Quarry consists of lower units that are abraded coral-stromatoporoid skeletal packstones (Fig. 2), with an interval of abraded coral-stromatoporoid grainstone. Upwards through the Cou Falls Member, the number of corals decrease and the number of stromatoporoids increase. Coral corallum and stromatoporoid coenostea morphology also change from bulbous hemispherical forms to elongate and digitate forms higher in the section, reflecting adaptation to more mud-rich environments. The Iowa City Member consists of pelleted mudstones, packstones and grainstones, with birdseye fenestral structures in muds indicating subaerial exposure. Overlying the birdseye interval is a skeletal wackestone unit that represents a slight deepening following the first subaerial exposure. The facies architecture of the Coralville Formation is believed to have exerted a strong influence on spatial heterogeneities in fluid-rock interactions during the lithification of the units.

Earlier work has established that successive T-R

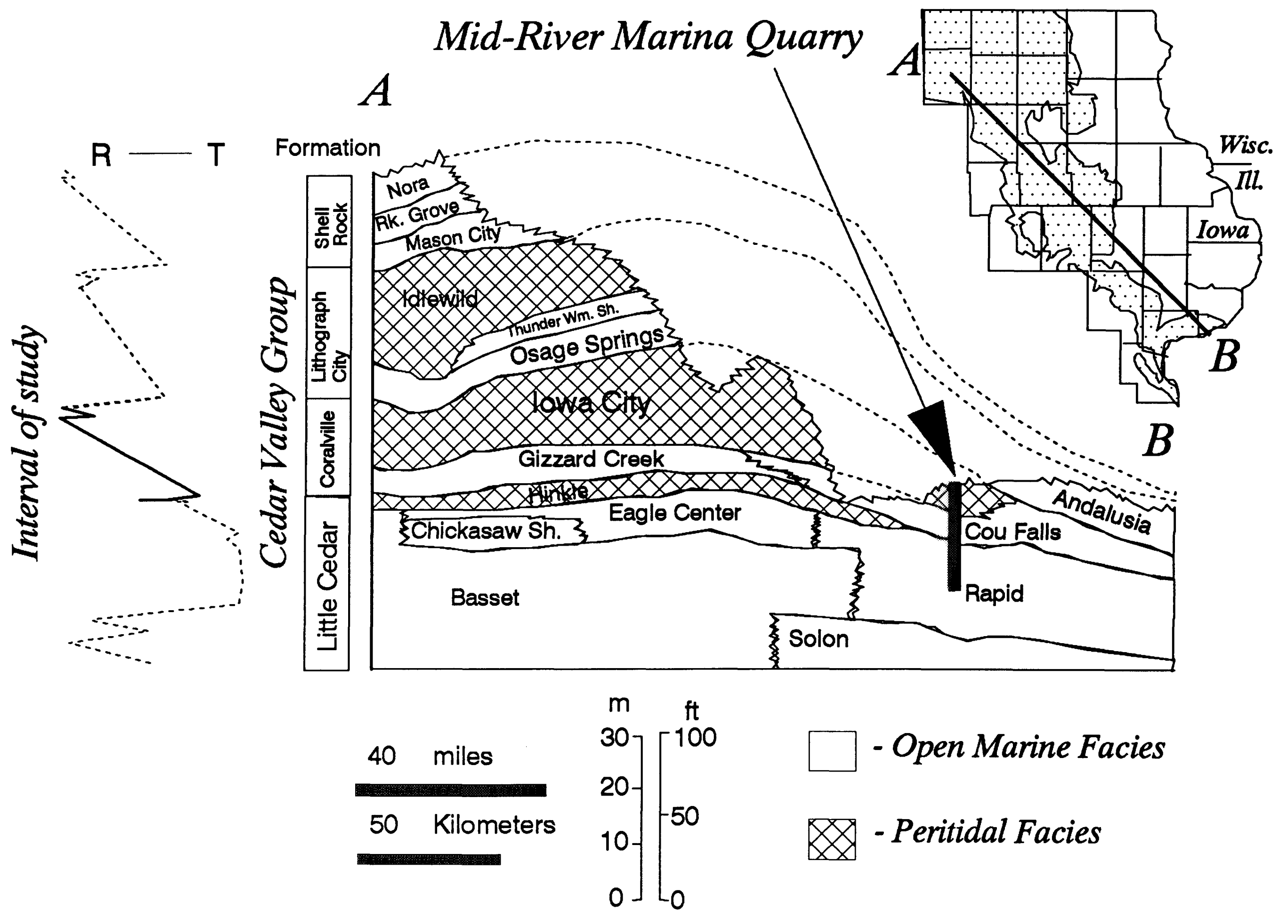

Figure 1. Regional lithic cross-section of the Cedar Valley Group with sea-level curve (from Witzke et al., 1988).

cycles in the Cedar Valley Group were lithified during successive meteoric events coinciding with intervals of subaerial exposure ending each depositional cycle (Plocher and Ludvigson, 1989; Plocher, 1990, Plocher et al., 1990a,b). As with other units, the rocks of the Coralville Formation were chemically stabilized by meteoric phreatic fluids in a gravity-driven groundwater flow system. The constructional depositional topography of the Coralville Formation, with a prominent shelf break at the depositional limit of the peritidal, Iowa City Member in Johnson County (Plocher and Ludvigson, 1989), permits us to reconstruct the geometry of the ancient meteoric groundwater flow system in the unit. Efforts to numerically model this flow system by computer simulation are underway (Plocher et al., in review).

The mud matrix-dominated Iowa City Member would have had a relatively low original permeability compared to the skeletal packstones of the underlying Cou Falls Member. Within the Cou Falls, there is a thin interval of grainstone that would have been more permeable as compared to the enclosing packstones. Differences in the original permeability of these vertically-stacked units would have had an effect on fluid flow and resulting fluid and rock chemistries.

METHODS

Lithic samples were collected from the rock succession at Mid-River Marina Quarry; polished slabs and thin sections were prepared (Fig. 2). Brachiopods were identified to the generic level from polished slabs. Brachiopods from two genera were chosen for analysis due to the lack of a single genus that is present throughout the interval. *Seratrypa* is common in the

Mid-River Marina Quarry
Type Cou Falls Member, Coralville Formation

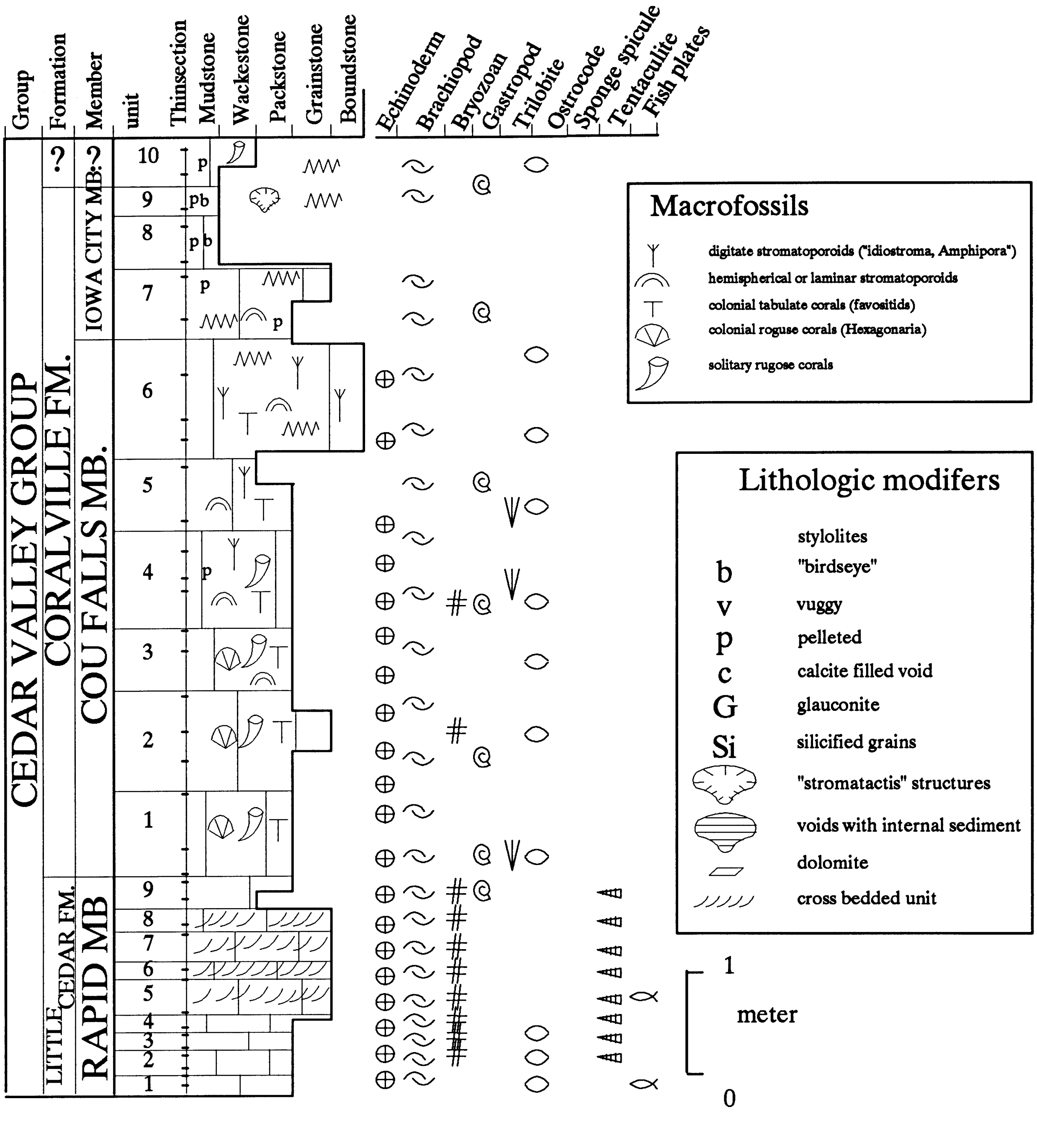

Figure 2. Graphic section of the Mid-River Marina quarry, the type Cou Falls.

lower portion of the interval and *Athyris* is common in the upper part of the sequence. There is a single interval in which the two genera coexist, the upper part of unit 2 (Fig. 2). The cathodoluminescent character of brachiopods were documented and non-luminescent brachiopods were microdrilled for isotopic analysis. Micrites from the same intervals as the brachiopods were also microsampled for isotopic analysis. Fibrous marine cements identified in the lower portion of the sequence were microdrilled for analysis as well.

Samples for isotopic analyses were roasted *in vacuo* at 380° C and analyzed using a Finnigan MAT 251 ratio mass spectrometer, at the University of Michigan Stable Isotope Laboratory, Department of Geological Sciences at the University of Michigan.

COMPONENT CHEMISTRY

Three components in the limestones were chosen for isotopic analysis. Isotopic analyses of nonluminescent brachiopods and fibrous marine cements are used to attempt to characterize calcite precipitated in equilibrium with marine fluids (Lohmann and Walker, 1989; Given and Lohmann, 1985; Popp, 1986). In the sequence under consideration, only one occurrence of marine cements has been noted, as a void filling inside of a whole-shell brachiopod. Brachiopods, on the other hand, are fairly common through the section, excluding the upper 50 cm of lithographic limestones (Fig. 2). Brachiopods used for paleocompositional information should be compared with data from other constituents, and should further be evaluated in light of stratigraphic, depositional, and diagenetic relationships (Rush and Chafetz, 1990, Plocher et al., 1990b). Micrite samples were analyzed from the same intervals as the brachiopods to provide a contrast between presumably least-altered components with presumably more altered components.

Brachiopods

The stable isotopic compositions of all sampled components are illustrated in (Fig. 3). There are two discrete clusters of brachiopod data, one group has considerably higher ^{18}O and ^{13}C values than the other. The clusters collectively comprise a linear field that could be interpreted to represent the solid-phase mixing of less-altered brachiopod shell material ($\delta^{18}O \approx -4$; $\delta^{13}C \approx +2$) and an isotopically lighter diagenetically altered end member ($\delta^{18}O \approx -7.75$; $\delta^{13}C \approx -3$). These data suggest that not all nonluminescent brachiopods are equally pristine in their degree of preservation. All brachiopods sampled were nonluminescent, although those in the isotopically depleted group are interpreted to have undergone significant alteration by interaction with an isotopically lighter fluid, presumably meteoric in origin.

Marine cements

Marine cements in the lower Cou Falls Member have a "patchy" cathodoluminescent character that is not related to constructive crystal growth zonation. This suggests some degree of neomorphic alteration of the cement. The marine cements have an oxygen isotopic composition slightly higher than the most enriched brachiopods. If the isotopically-enriched brachiopods are interpreted as least altered, then the marine cements yield closely similar oxygen isotopic ratios. The marine cements could be slightly less altered than the least-altered brachiopods with respect to oxygen isotopes. The carbon isotopic compositions of the marine cements are notably lighter than the most isotopically depleted brachiopod group; this could have been accomplished through the generation of pore fluids with dissolved CO_2 produced by the microbial degradation of organic matter in muddy sediments below the sea floor. The marine cements may have precipitated from modified marine pore fluids, possibly in the sulfate reduction zone. Fine-grained sedimentary sulfides are a prominent feature in the Cou Falls Member replacing matrix and skeletal grains.

Micrites

The isotopic compositions of the micrites form a distinct linear trend, from an enriched end member ($\delta^{13}C \approx +0.5$; $\delta^{18}O \approx -5.5$), and a depleted end member of ($\delta^{13}C \approx -3.0$; $\delta^{18}O \approx -7.0$). These compositions are not as enriched as the heaviest brachiopods, but also are not as depleted as the lightest brachiopod calcites. This trend is interpreted to represent the solid phase mixing of less-altered micrites and isotopically lighter altered micrites. The heaviest micrites are lighter than the isotopically heaviest brachiopods because they are believed to be more susceptible to diagenetic alteration than are brachiopods. All the micrites are more enriched in ^{18}O and ^{13}C than a small population of most-altered brachiopods. This relationship could result from different original mineralogies of micrites in the sequence. The micrites in the upper portion of the sequence are pelletal. The different apparent initial compositions of the stratigraphically higher micrites

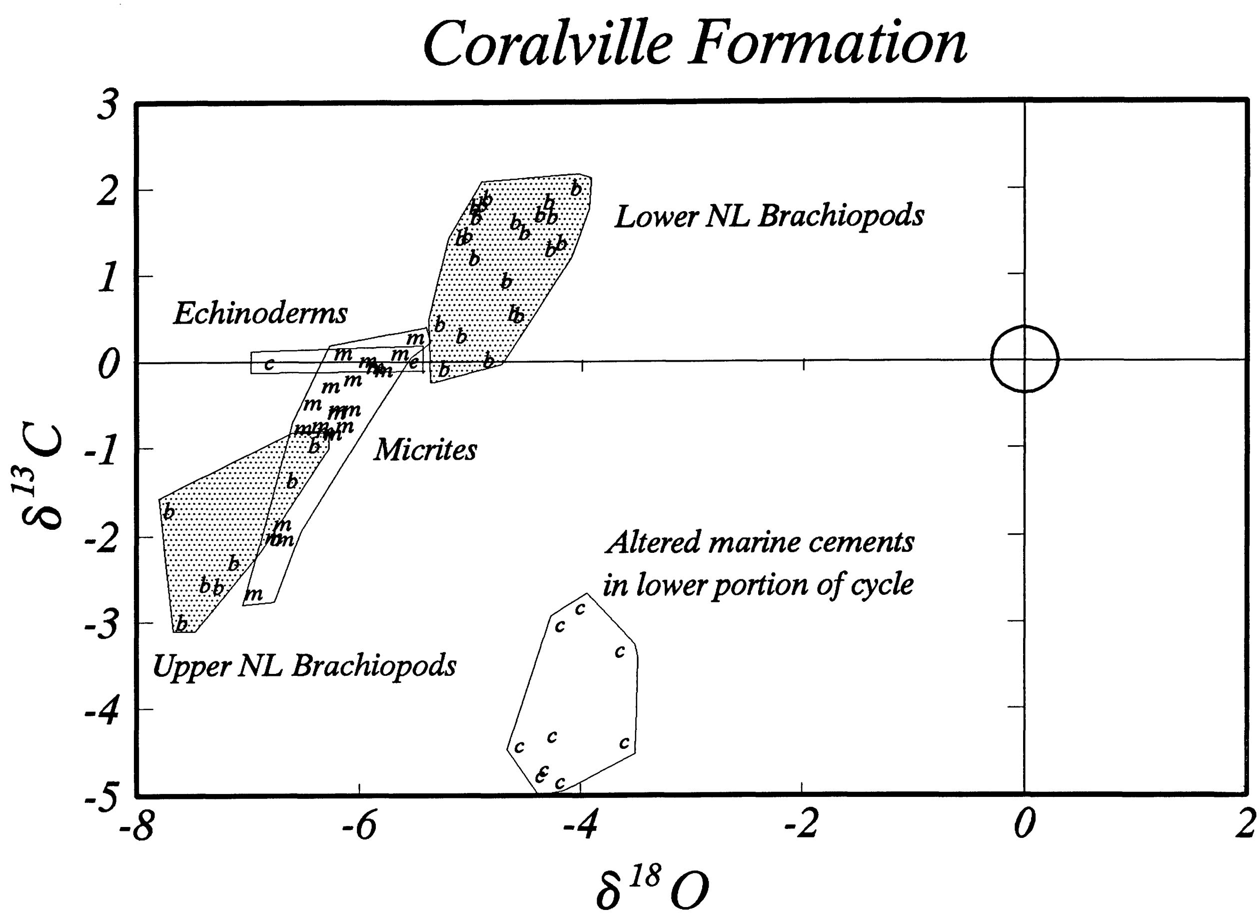

Figure 3. Carbon and oxygen plot of carbonate components in the Coralville Formation.

and brachiopods could have resulted in differing end compositions, after interaction with and alteration by meteoric fluids. In hopes of addressing this fundamental question, additional sampling is underway to define the oxygen isotopic composition of meteoric calcite in the Coralville Formation.

VERTICAL SEQUENCE

Plotting isotopic data according to stratigraphic position is a useful approach to interpreting diagenesis in relation to depositional cycles. The means and standard deviations of isotopic compositions of components at each sample interval are plotted in Figure 4. There is a remarkable covariance in $\delta^{13}C$ and $\delta^{18}O$ for each component. The brachiopod data can be used to divide the vertical sequence into two intervals. The upper interval contains brachiopods depleted in ^{13}C and ^{18}O. The lower interval, below the 450 cm level, is characterized by brachiopods that are enriched in both ^{13}C and ^{18}O. The micrites, which are more susceptible to diagenesis, have a less marked signal, but in general they show a depleted upper interval and a lower interval (below the 450 cm level), which contains the most enriched values in the sequence. These data are consistent with our present understanding of diagenesis within T-R cycles of the Cedar Valley Group. Directly underlying a subareal unconformity is an interval characterized by fluid-dominated, relatively open-system diagenesis, resulting in depleted isotopic compositions of all components, including brachiopods (Fig. 5). As meteoric fluids migrated down flow in this paleo-groundwater flow system, they became isotopically enriched due to progressive rock-water interaction. These enriched fluids produced a lower interval characterized by rock-dominated, relatively closed-system diagenesis (Fig. 5). Small intervals with

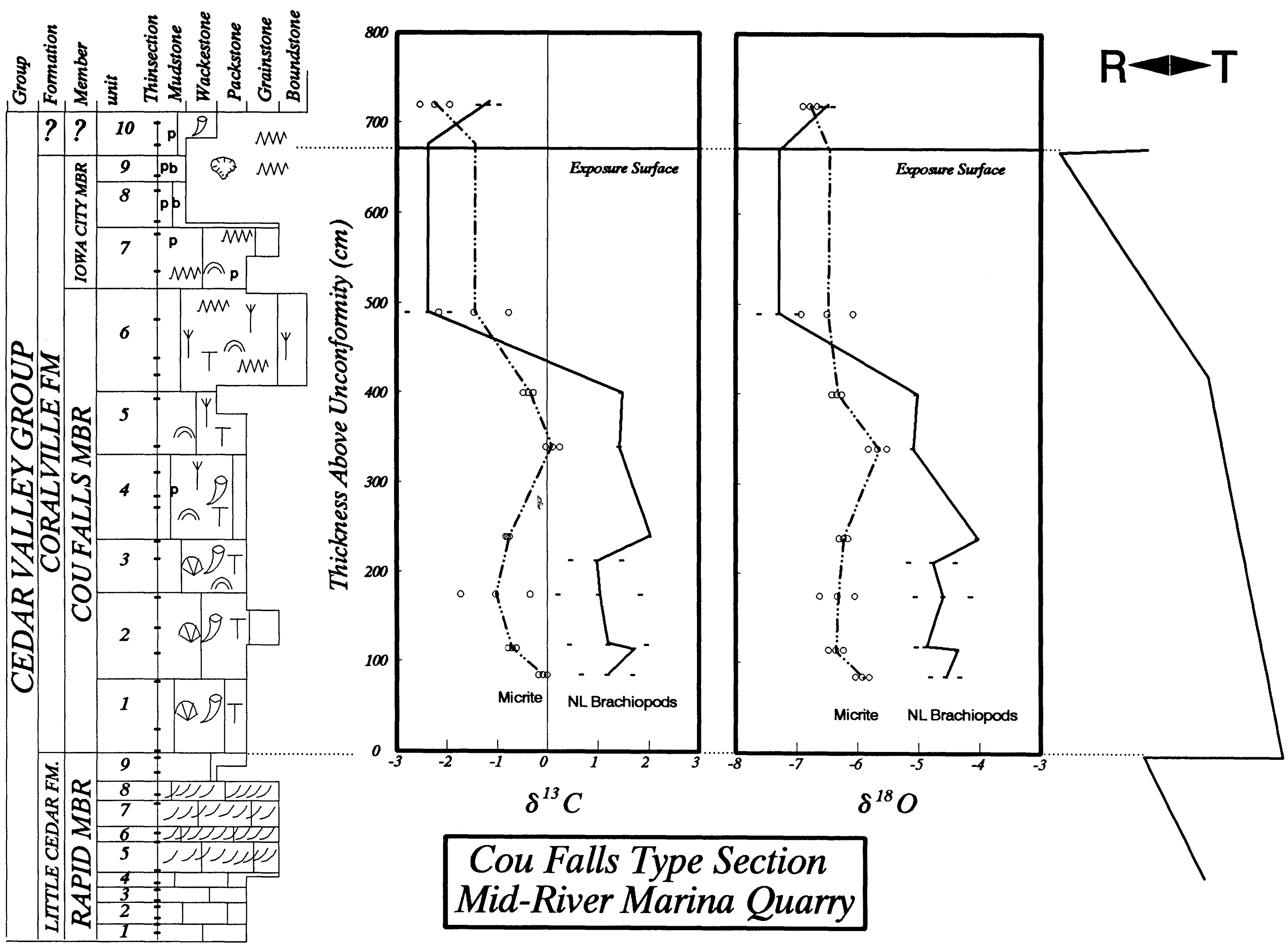

Figure 4. Lithic section and vertical plots of mean isotopic compositions of components for the Coralville Formation with sea-level curve.

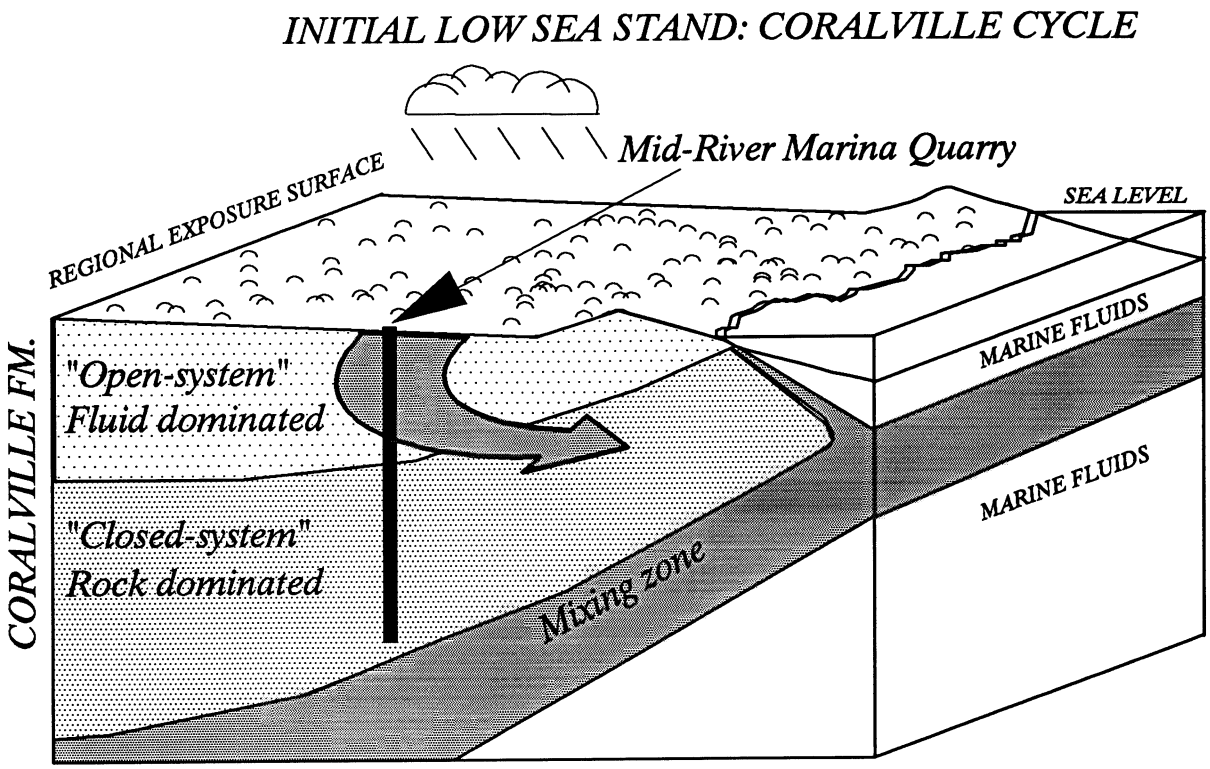

Figure 5. General diagenetic model for the initial off-lap of the Coralville Formation.

deflections in the curve, sharing coincident relative carbonate oxygen isotopic depletions of micrites and brachiopods in the lower interval, could reflect original differences in sediment permeability and fluid flow rates, which resulted in varying fluid compositions of and rock chemistry.

CONCLUSIONS

The cathodoluminescence character of brachiopods is useful for identifying least-altered brachiopods within a given interval, but certain intervals could have undergone extensive meteoric alteration and contain non-luminiscent brachiopods that record that alteration. In most Paleozoic sequences, brachiopods are much more common than marine cements, and can be considered to be the least-altered component after giving careful consideration to brachiopod identification, cathodolumiscence, trace-elemental and stable isotopic data, and stratigraphic position relative to subaerial exposure surfaces (Rush and Chafetz, 1990). In the Coralville T-R cycle, the transgressive lower units are less altered than the overlying regressive facies, and the least-altered composition of marine calcite for this interval is $\delta^{18}O \approx -3.5$ and $\delta^{13}C \approx +2$, as interpreted from marine cements and nonluminescent brachiopods.

ACKNOWLEDGMENTS

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A PALEOMAGNETIC STUDY OF MIDDLE DEVONIAN CARBONATES FROM IOWA AND MANITOBA

by

David F. Parse, Jr. and Peter W. Plumley
Heroy Geology Laboratory
Syracuse University
Syracuse, New York 13244-1070

INTRODUCTION

This study is aimed at resolving a reliable Middle Devonian paleomagnetic pole for cratonic North America. Previous studies have been unsuccessful, as all have shown Permian overprints (McCabe and Elmore, 1989; Bethke and Marshak, 1990). In studying the interior craton, the original hope was to avoid the Permian overprinting by maintaining great distance from the origin of the Permian event, the Alleghenian Orogeny. Two main target areas were selected, eastern Iowa and southwestern Manitoba, because they fulfilled or presented the possibility of fulfilling several criteria: 1) sufficient distance from Alleghenian deformation and related fluid migration (believed to be the cause of Permian overprinting in previous Middle Devonian cratonic studies), 2) excellent age control of stratigraphy, 3) contained units which spanned at least 1 million years in age, and 4) contained units which carried a primary hematitic component.

One of the most troublesome aspects of paleomagnetics today is the uncertainties associated with the definition of reference poles. Poles thought to be firmly established can suddenly come into question with the presentation of one or two reliable, yet discordant results. Any discordant result must be explained, and may lead to reconfiguration of the APWP if shown to be accurate. Because of this potential for drastic alterations of any APWP record, certain reservations must always be placed in conclusions drawn from such data bases. This is particularly the case for especially underrepresented data sets, such as the Middle Paleozoic APWP record for North America.

LOCATION AND STRATIGRAPHY

In eastern Iowa the Middle Devonian carbonate sequence was extensively sampled (275 cores) by drilling cores with a standard Pomeroy drill setup. Most samples were taken from five quarries (Fig. 1), four of which contained the Givetian age Little Cedar, Coralville, and Lithograph City formations (Klein, Conklin, Garrison, and Buffalo quarries). The Eifelian age Spillville Formation was sampled in the Spillville quarry.

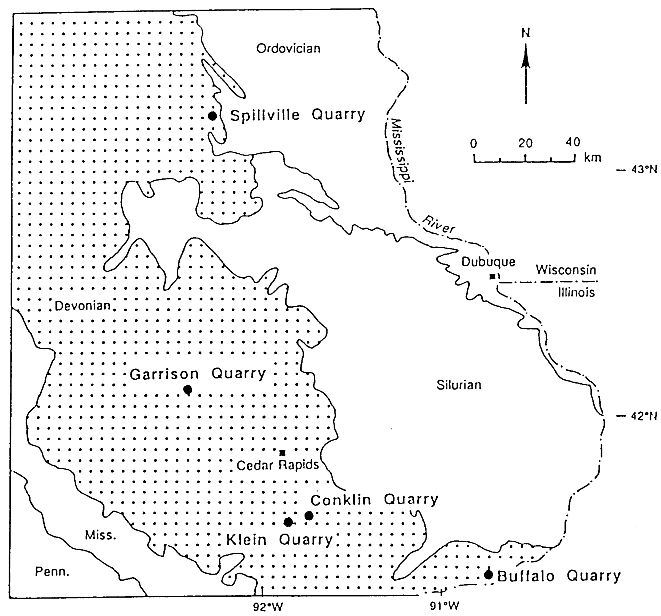


Figure 1. Sample locations for paleomagnetic sites in eastern Iowa. Quarries marked by solid dots. Devonian outcrop belt shown with dot pattern.

Sampling of outcrops and quarries in southwestern Manitoba took place in three separate areas (Fig. 2). The entire Middle Devonian sequence was sampled (190 cores in total), with several units being of particular interest. The Ashern Formation (lowermost unit of Elk Point Group) holds the most promise as it is brick red in color, and therefore may contain a primary hematitic component. The Mafeking Member (lower-

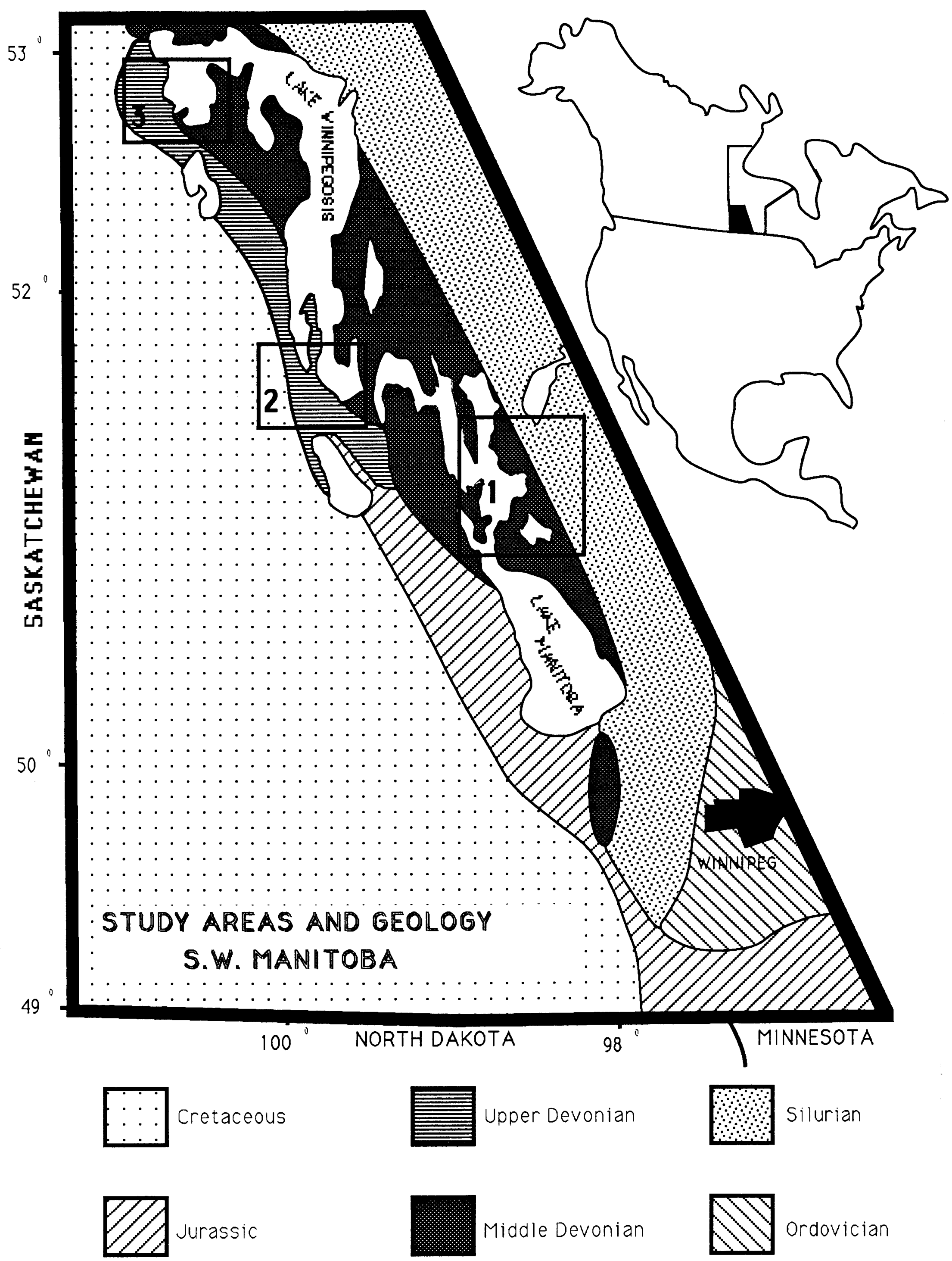


Figure 2. Study areas (after Day et al., 1991) and generalized geologic map of southwestern Manitoba (after Norris, et al., 1982). Squares mark general sampling regions.

most Dawson Bay Formation) and the First Red Beds Member (lowermost Souris River Formation) also potentially contain a primary hematitic component.

The carbonate sequences from both Iowa and Manitoba represent excellent paleomagnetic targets as they all fulfill at least three of the four sampling criteria (only the Ashern Formation and the Mafeking and First Red Beds Members may potentially fulfill the final criterion). Both areas have great lateral separation from regions of Alleghenian deformation, both have excellent age control, and both contain units of at least moderate thicknesses.

Age control of both areas is well constrained by conodont and brachiopod zonations (Fig. 3). The established stratigraphic and biostratigraphic correlations (Fig. 3) between Iowa and Manitoba also allow for paleomagnetic correlations between the two sequences, and may aid in correlating strata-bound reversals.

PALEOMAGNETIC RESULTS

Iowa

As typical of carbonates, the natural remanent magnetizations (NRMs) are extremely weak, with intensities ranging from 6x10-9 to 2x10-7 emu/cc. A relatively large percentage of the samples have not progressed past the NRM stage of paleomagnetic analysis due to their weak nature, as the NRM intensities are less than the noise of the Schonstedt magnetometer used in the Syracuse University lab (1x10-8 emu). Samples with higher NRM intensities were subjected to stepwise thermal and alternating field demagnetization. Comparison of both demagnetization techniques show thermal demagnetization to be more effective due to the magnetic nature of the samples, and therefore thermal demagnetization has been the primary technique for both the Iowa and Manitoba samples.

Although intensities are weak, stable and reproducible directions have been obtained from samples with intensities as low as 1x10-8 emu/cc. Vector difference diagrams (Fig. 4) are used in displaying the demagnetization behavior, while quantitative principle component analysis (Kirschvink, 1980) has been used to calculate the different vector components present in the samples. Figure 4 shows vector difference diagrams from three separate samples which illustrate the four different components of magnetization that have been isolated from the Iowa samples.

The first component, removed in all samples (usually removed by 250C), is called the tertiary component, and has a mean direction of (Dec=5.6, Inc=80.5, a95=6.8). In Figures 4a, b and c, this component is demonstrated by a northerly and steep down direction. Figure 5a shows a stereonet projection of the tertiary component in direction space. The great deal of scatter present may possibly be attributed to the effects of quarry blasting on magnetic grains with low coercivities.

The secondary component is also present in all samples, and represents the dominant component of the four isolated components (Figs. 4a, b, and c). Although it is removed at a variety of temperatures (200 to 530C), depending on the magnetic properties of the specific sample, it is always a very distinct component. Its mean direction (Dec=157.3, Inc=-17.5, a95=6.9) and pole (Lat=52.1N, Long=126.0E, a95=5.8) correspond very closely to an expected Permian direction and pole for Iowa (Table 1), and therefore indicate the presence of Permian age overprinting of the samples.

Although the presence of the Permian overprint is obvious, there are two other stable components of magnetization that are removed at higher unblocking temperatures than the Permian component. These two components have been termed characteristic component A, present in most samples, and characteristic component B, present in only 9 of the samples. Characteristic component A is illustrated in Figures 4b and c as the final two demagnetization steps, which approach the origin from a southeasterly and down direction. The mean direction (Fig. 5c) and pole of this component is (Dec=169.1, Inc=21.2, a95=10.3; Lat=35.2N, Long=101.4E, a95=9.4). Characteristic component B (Figs. 4a and 5d) has a mean direction and pole of (Dec=83.5, Inc=-81.0, a95=17.4; Lat=38.5N, Long=252.5E, a95=30.4). The high a95s of characteristic component B are attributed to the low number of samples.

Manitoba

Results from Manitoba are preliminary, with thermal demagnetization and component analysis limited to 8 of a total 27 sites. NRMs are again characteristically weak, with intensities ranging from 6x10-9 to 2x10-6 emu/cc. Vector difference diagrams of a few samples (Fig. 6) indicate several peculiarities of the Manitoba samples as compared to those from Iowa. All samples from Iowa contain both tertiary and secondary components, and most contain a final characteristic component. This is not the case with the Manitoba samples, as they do not show the same degree of consistency. While preliminary tertiary (Lat=71.3N, Long=280.6E), secondary (Lat=52.8N, Long=124.6E)

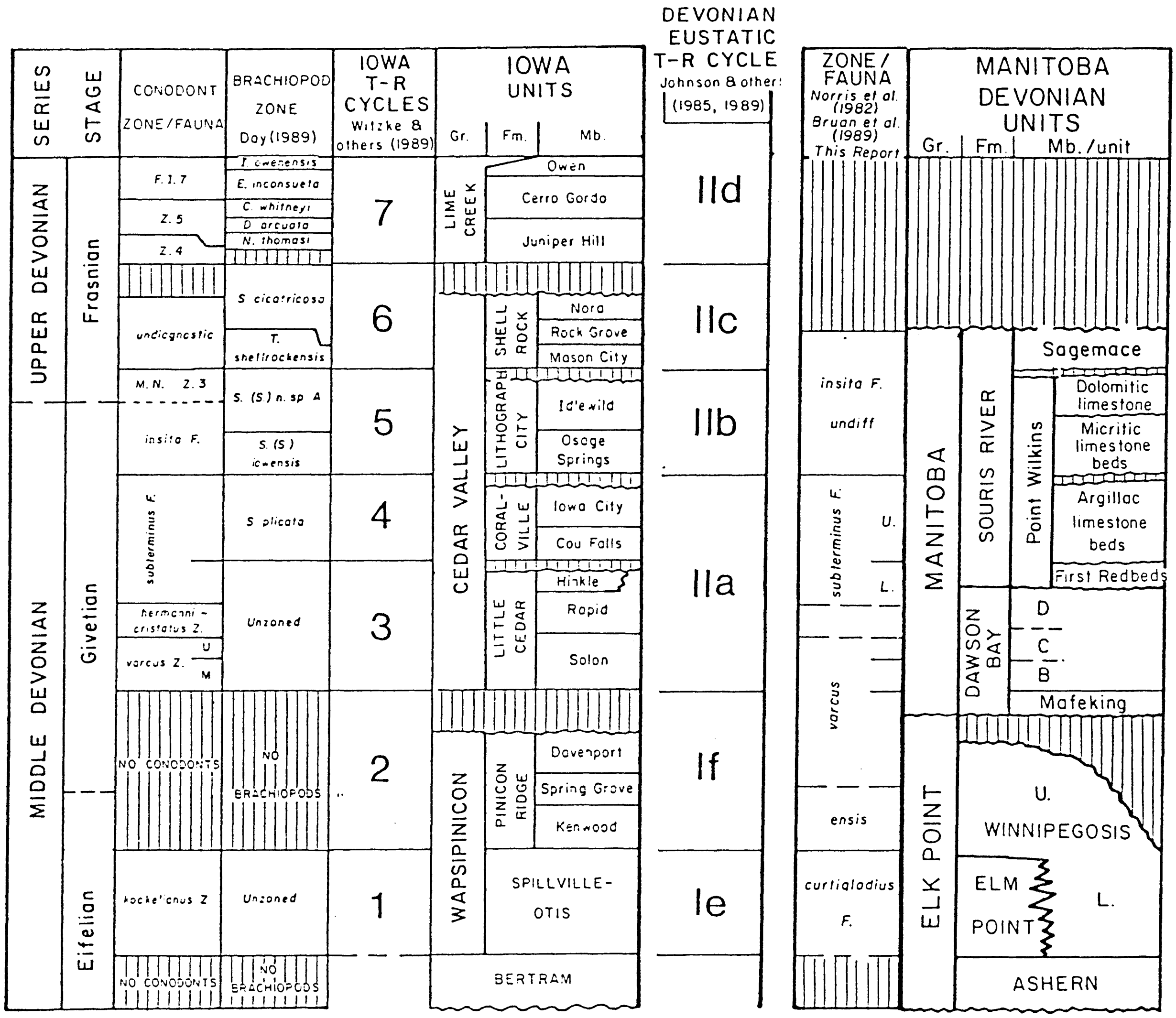
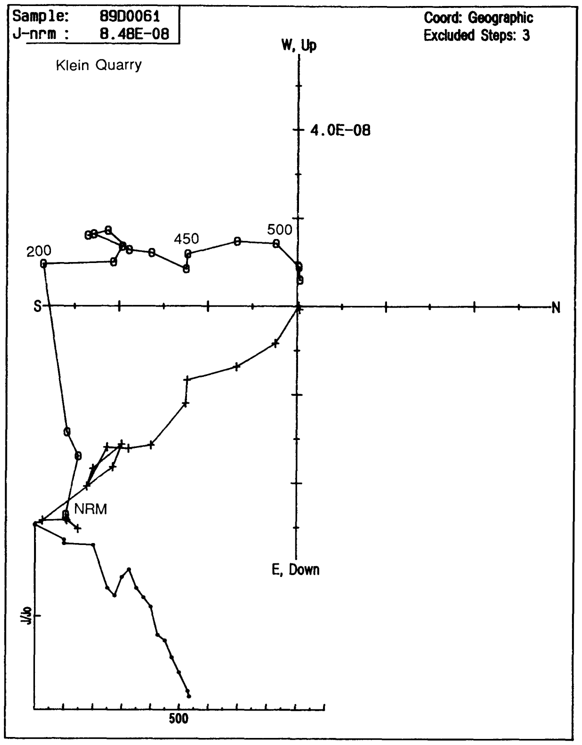
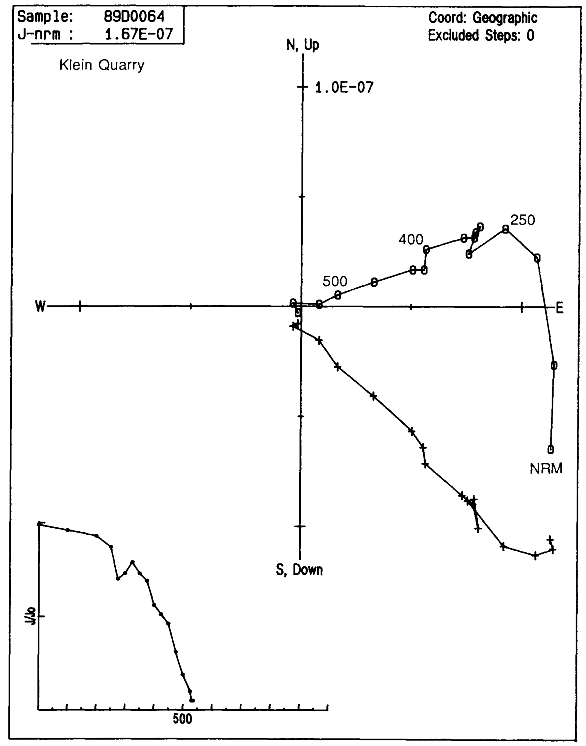


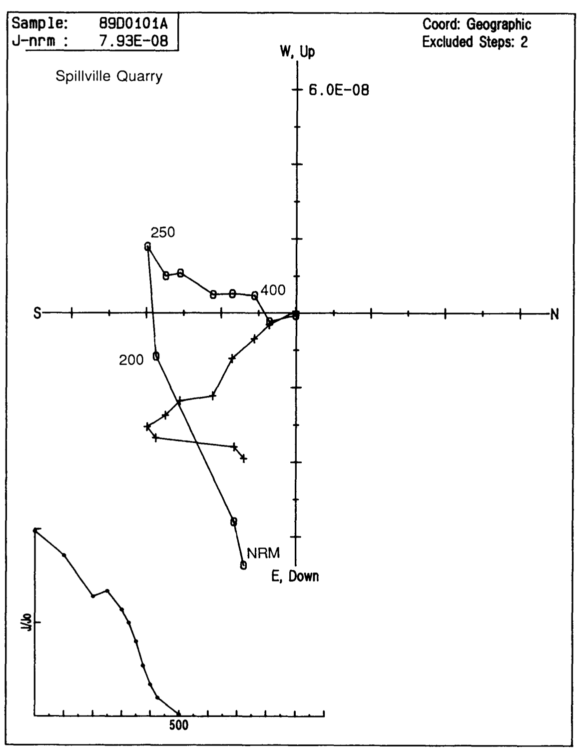
Figure 3. Stratigraphic and biostratigraphic correlations between the Middle and Upper Devonian strata of eastern Iowa and southwestern Manitoba (Day, et al., 1991). Iowa conodont sequence summarized in Witzke et al. (1989) and Day (1990). Manitoba conodont sequence summarized in Norris et al. (1982).



A



B



C

Figure 4. Vector difference diagrams showing thermal demagnetization behavior of three samples from eastern Iowa. Plus symbols represent declination, open circle symbols represent inclination. Normalized J/Jo versus temperature plots show unblocking temperature spectra and thermal stability of each sample.

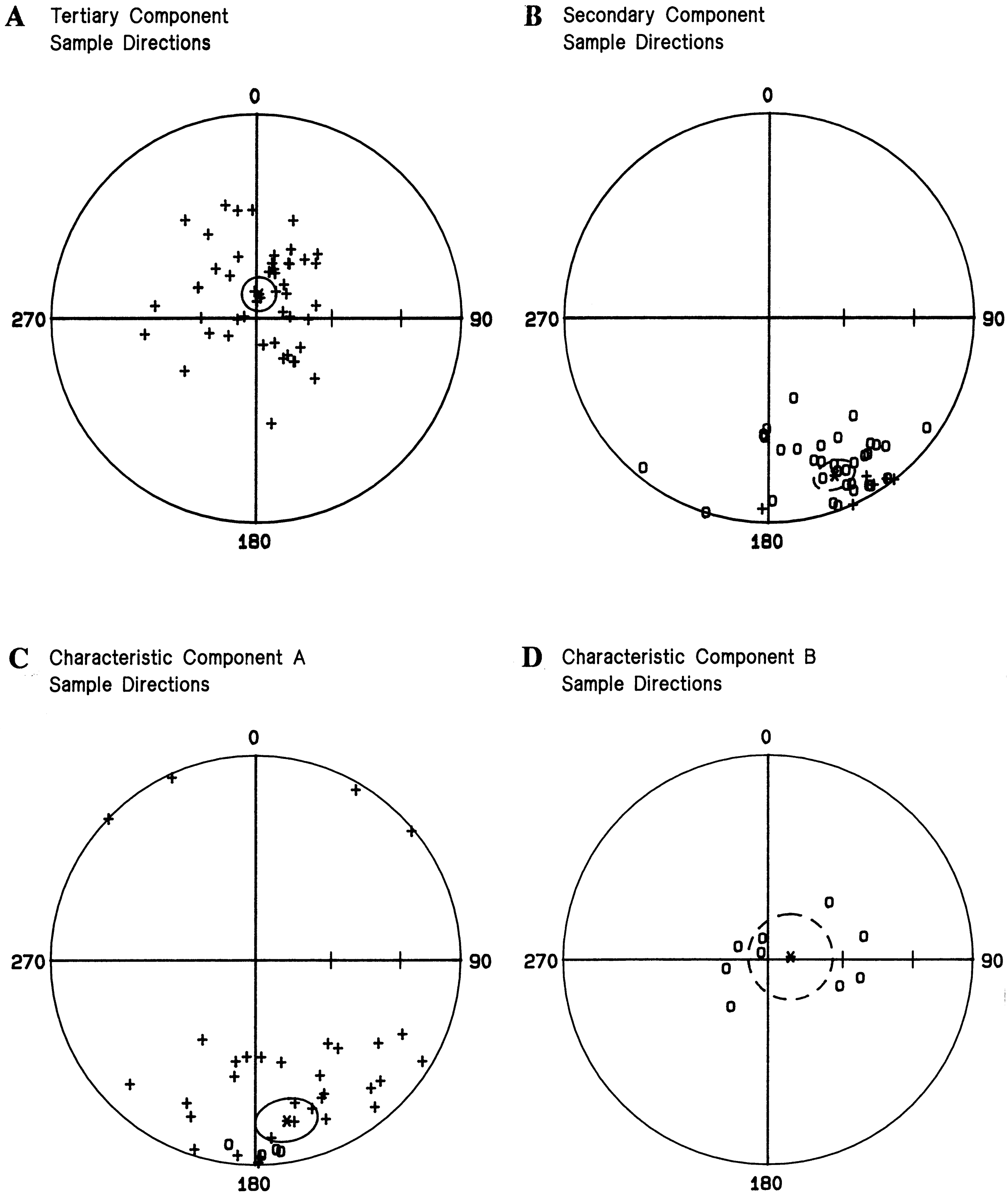


Figure 5. Equal area projections of sample directions from eastern Iowa showing the four magnetic components isolated in the samples. Plus symbols represent positive (down) directions, open circle symbols represent negative (up) directions. Ovals of 95% confidence are plotted about each mean.

Table 1.

Expected Iowa Directions and Poles:		**(42N, 92W)**
	Directions (Dec.,Inc.)	Poles (Lat.,Long.)
Upper Devonian	166, 33	22N, 123E
Lower Devonian	182, 33	30N, 86E
Permian	157, -2	44N, 121E
Tertiary	351, 57	82N, 147E
Calculated Iowa Directions and Poles:		
Middle Devonian	169, 21	35N, 101E
Permian	157,-18	52N, 126E
Tertiary	6, 81	58N, 274E
Expected Manitoba Directions and Poles:		**(52N, 100W)**
	Directions (Dec.,Inc.)	Poles (Lat.,Long.)
Upper Devonian	140, 14	22N, 123E
Lower Devonian	175, 15	30N, 86E
Permian	151,-24	44N, 121E
Tertiary	349, 66	82N, 147E
Calculated Manitoba Directions and Poles:		
Middle Devonian	154, 8	30N, 112E
Permian	154,-35	53N, 125E
Tertiary	17, 79	71N, 281E

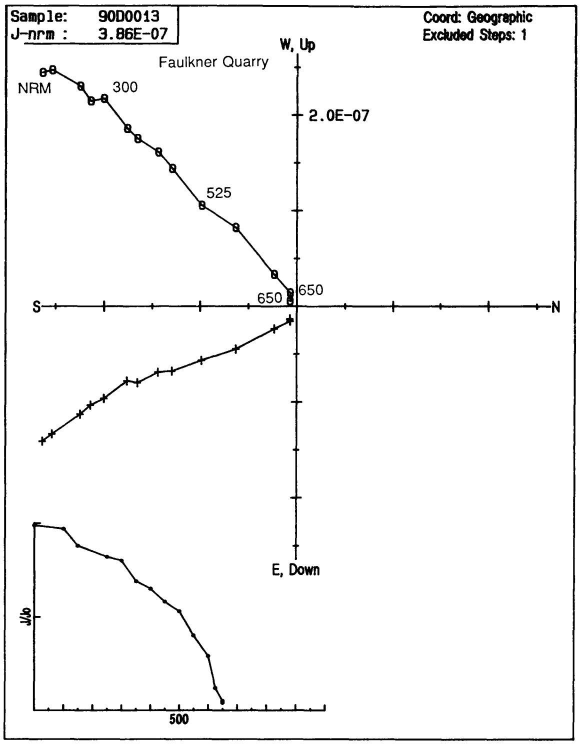
Mean Middle Devonian Pole (Averaged from Iowa and Manitoba)

#	Lat	Long	a95	K
45/44	34.4N	103.4E	8.3	7.7

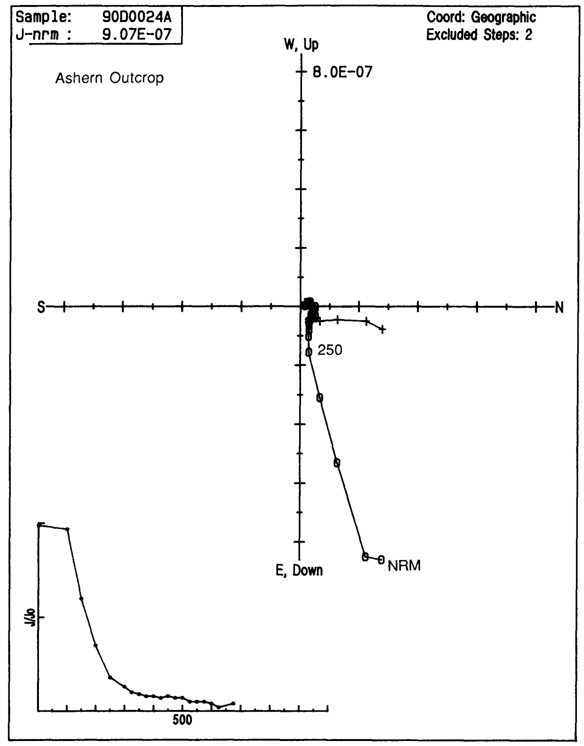
and characteristic (Lat=30.2N, Long=112.4E) mean poles have been calculated (Fig. 7), there are several samples which demonstrate odd, and currently unexplainable, demagnetization patterns. Figure 6a shows a sample which contains only one component of magnetization, a southeasterly and down (secondary) direction. Figures 6b and c (6c is the same sample as 6b, but the first few demagnetizations steps are removed to show greater detail closer to the origin) show a sample which has a northerly and steep down component (tertiary) and a southeasterly and down component (characteristic), but no Permian component. Figures 6d and e (again the same sample blown up for detail) show a sample which contains typical tertiary and characteristic components, but a secondary (northeasterly and down) component which does not correspond to any direction expected from the APWP. Finally, Figure 6f is a sample which contains three components which correspond closely to the mean directions for Manitoba (Fig. 7).

Although the Manitoba samples do not show the same consistency as the Iowa samples, it has been possible to calculate poles for the Manitoba sequence, and these poles correspond well to those calculated from Iowa. The few odd components present in the Manitoba samples are spacially isolated enough so as to have no detrimental effect on the calculation of any component recorded in the samples. The dominant components, the tertiary, secondary and characteristic components, are present in a sufficient number of samples to allow the calculation of mean Manitoba poles.

The cause of the inconsistencies is uncertain at this point, but it appears to be specific to the lower stratigraphic units. All but one of the sites with odd sample components comes from the Ashern Formation, with the one exception (Fig. 6a) coming from the lowermost Elm Point Formation. This site is stratigraphically just


Sample: 90D0013
J-nrm : 3.86E-07
Coord: Geographic
Excluded Steps: 1
Faulkner Quarry
W, Up
NRM
300
2.0E-07
525
650
650
S
N
E, Down
J/Jo
500

A


Sample: 90D0024A
J-nrm : 9.07E-07
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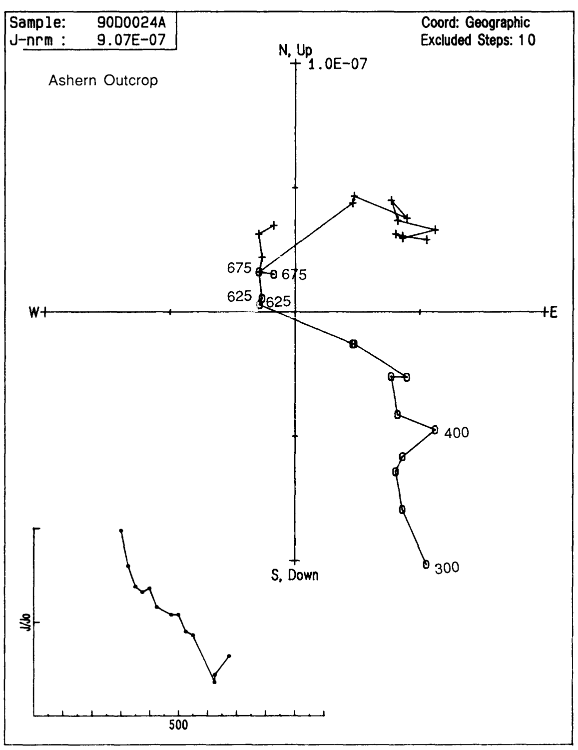
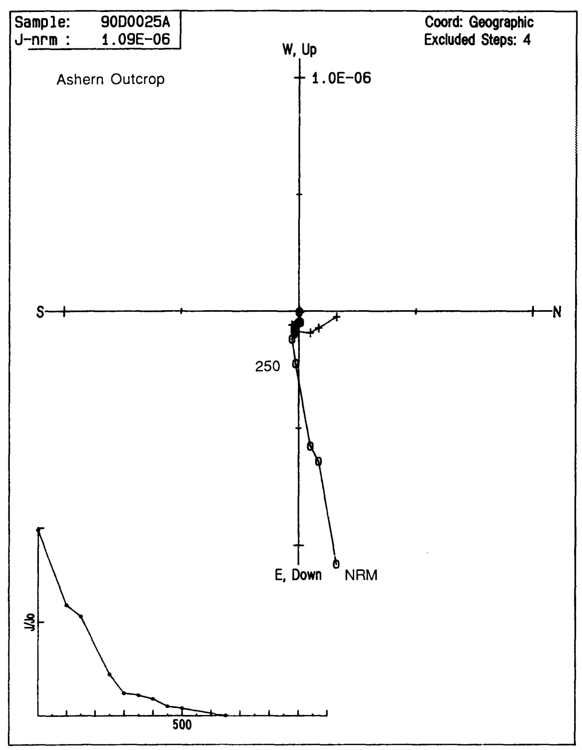
Excluded Steps: 2
W, Up
8.0E-07
Ashern Outcrop
S
N
250
E, Down
NRM
J/Jo
500

B


Sample: 90D0024A
J-nrm : 9.07E-07
Coord: Geographic
Excluded Steps: 10
N, Up
1.0E-07
Ashern Outcrop
675
675
625
625
W
E
400
S, Down
300
J/Jo
500

C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J-nrm : 1.09E-06
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Excluded Steps: 4
W, Up
1.0E-06
Ashern Outcrop
S
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NRM
J/Jo
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D

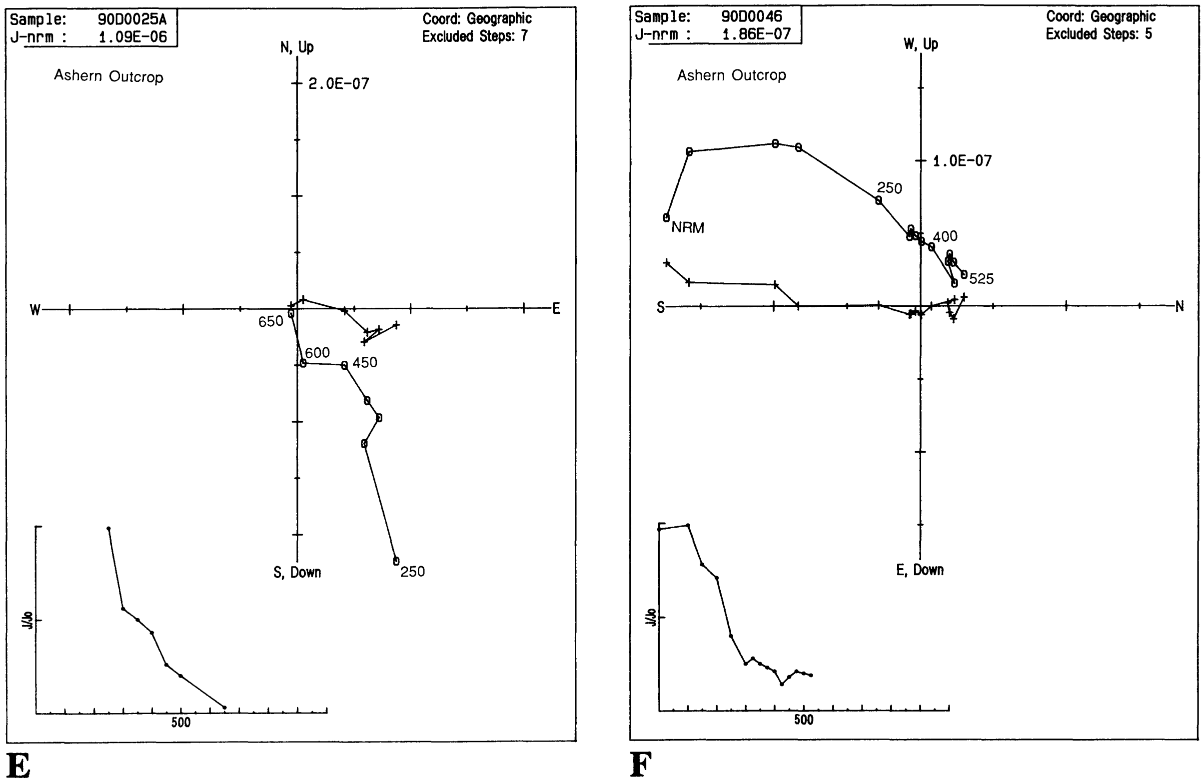


Figure 6. Vector difference diagrams showing thermal demagnetization behavior for four samples from southwestern Manitoba. Figures 6c and 6e are blown-up images of figures 6b and 6d, respectively. Symbols as noted in Figure 4.

above the Ashern Formation, and contains a reddish color, possibly indicating contamination from the Ashern. Therefore, the peculiarities may be the result of characteristics of the units from which the samples are derived.

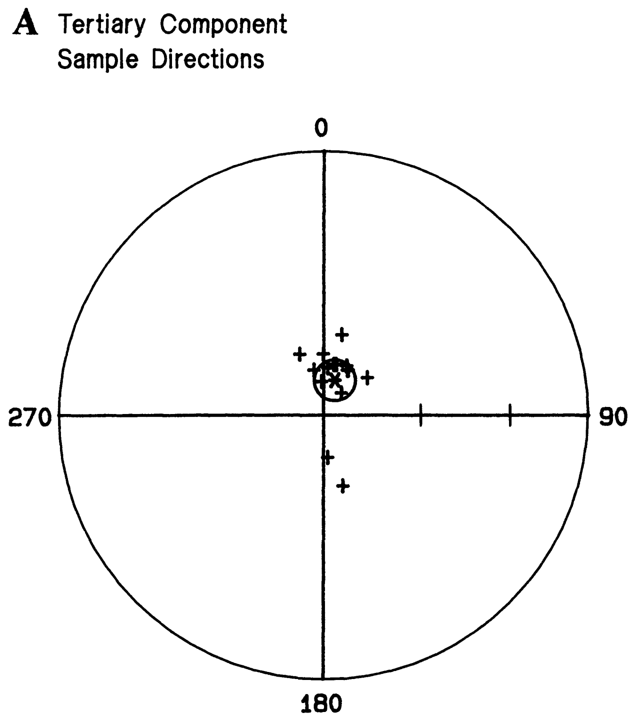
Correlation Between Iowa and Manitoba Results

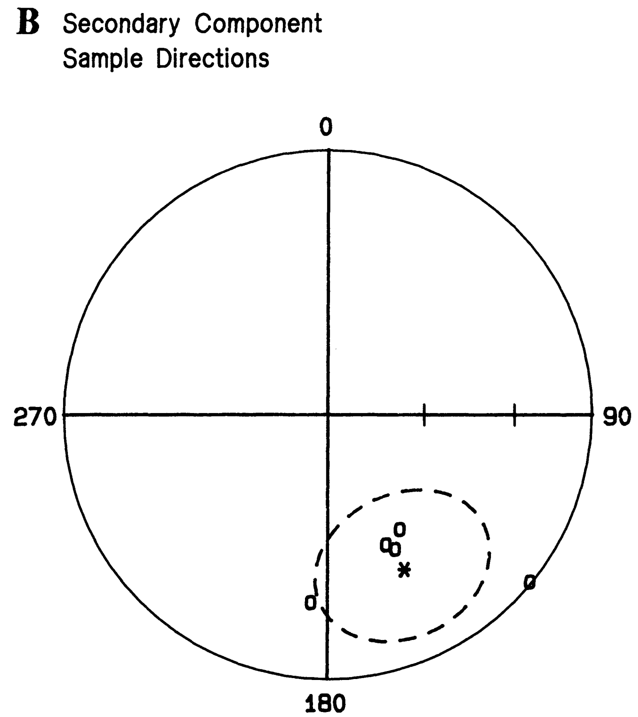
Paleomagnetic results from the Iowa sequence correspond very closely to the results from the Manitoba sequence. The mean Middle Devonian pole calculated for Iowa is (Lat=35.2N, Long=101.4E), while the Manitoba mean is (Lat=30.2N, Long=112.4E), as shown in Figure 8. The fact that the results are so similar lends credibility not only to the calculated Middle Devonian pole of this study, but also to using weakly magnetized carbonate units for paleomagnetic studies.

No further correlations have been conducted between the Iowa and Manitoba sequences, however other possibilities exist. Intensity variations throughout the stratigraphies of each sequence can be correlated, checking if variations occur in similar units. If so, explanations as to why fluctuations in intensity occur at certain geologic times will be a concern. Another possibility is the correlation of directional data. Strata-bound reversals, if present, can be correlated, as well as variations in site directions (assuming a large enough number of samples is available to provide statistical significance).

DISCUSSION

Results from this study to date have yielded four distinct components of magnetization (although the Manitoba sequence presents the possibility of establishing others), for which paleomagnetic poles have been calculated. Figure 8 shows the North American APWP with the calculated poles from Iowa plotted. Only the Middle Devonian pole from Manitoba is plotted in Figure 8, mainly because the Permian and Tertiary poles show large circles of uncertainty caused by the small number of total samples. However, comparison of the Iowa results with Manitoba results in Table 1 show very close correlation between pole





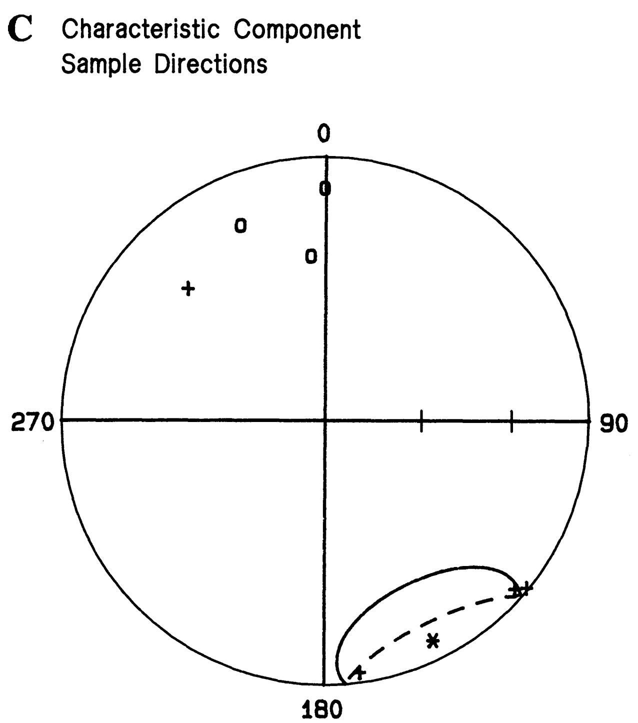


Figure 7. Equal area projections of sample directions from southwestern Manitoba showing the three magnetic components isolated in the samples. Symbols as noted in Figure 5 caption.

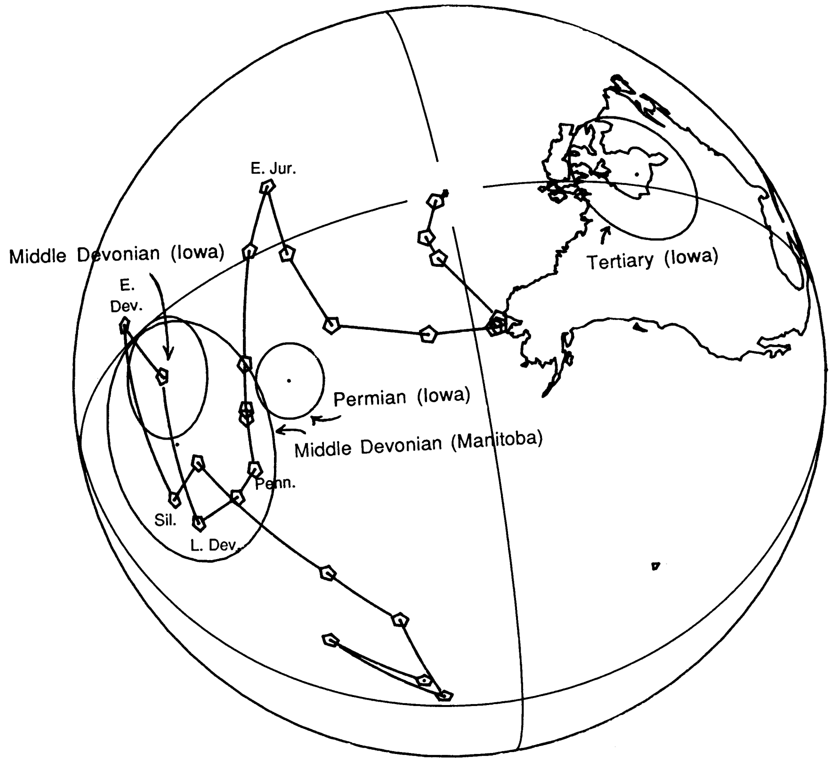


Figure 8. Oblique orthographic projection of the world showing the North American apparent polar wander path. Calculated poles from Iowa and the calculated Middle Devonian pole for Manitoba are plotted as labeled. Ovals of 95% are plotted about each pole. Pentagons represent reference poles for North America.

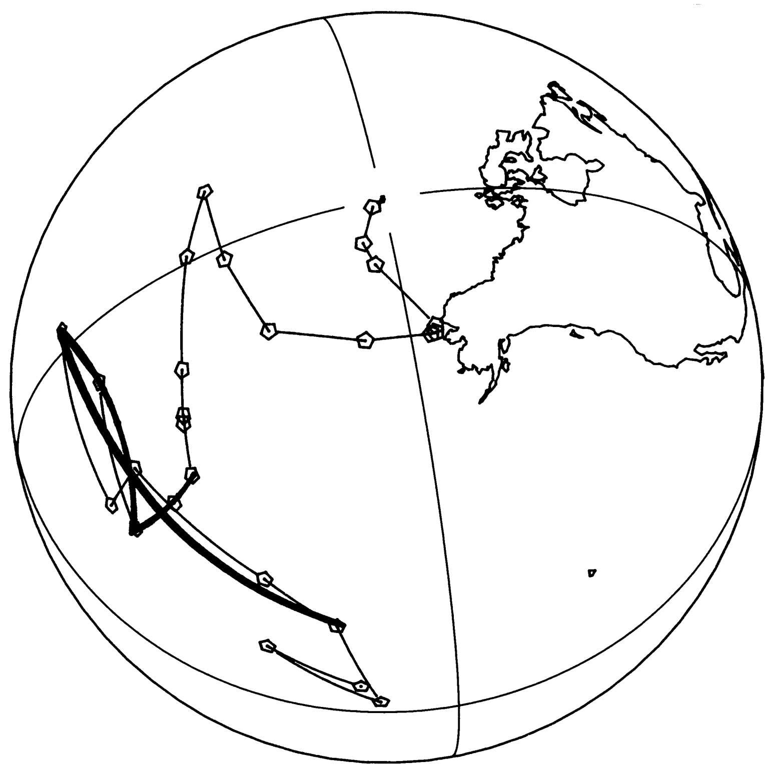


Figure 9. Oblique projection of the world showing three possible paleomagnetic Euler pole tracks (bold curves) as determined from the North America APWP. Symbols as noted in Figure 8.

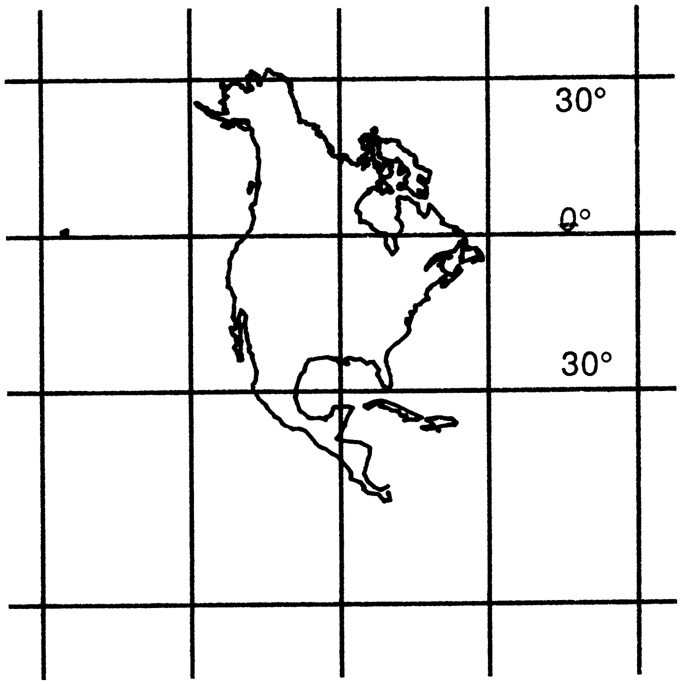


Figure 10. Middle Devonian paleolatitudinal reconstruction for North America based on our calculated pole.

coordinates of the Permian and Tertiary components.

The calculated tertiary pole from Iowa lies close to the expected Tertiary pole on the North American APWP, although it is near-sided. The secondary pole, without doubt, is associated with the Permian overprint, and therefore lies close (but again near-sided) to the expected Permian pole on the APWP. The pole calculated from characteristic component A lies on a track between the Early and Late Middle Devonian poles, and establishes a Middle Devonian pole for North America. The final component, characteristic component B, is not plotted because the cause of its magnetization is uncertain, although its directions seem to indicate that it is associated with a younger remagnetization event. Its pole coordinates (Lat=38.5, Long=252.5) indicate higher paleolatitudes, and therefore a younger event, than would be expected for either the Devonian or Permian.

As a result of the establishment of a Middle Devonian pole, these interior cratonic carbonates show that while the problems associated with the Permian overprint have not been completely eliminated, the target units have shown the ability to preserve a Devonian signal at higher unblocking temperatures than the overprint. Therefore, although a chemical remanent magnetization (CRM) of Permian age has caused a degree of overprinting (McCabe and Elmore, 1989; Lu et al., 1990), it has not completely masked the primary Middle Devonian signal of the units. Further studies in these regions should help in better defining the Early Ordovician to Late Devonian APWP for North America.

Because of the weak nature of the Middle Paleozoic paleomagnetic database, interpretation of the APWP during this time span is very questionable. Assuming the Early and Late Devonian poles are reliable, which is risky because they are calculated from a limited number of studies, then a Silurian to Late Devonian hairpin loop exists in the North American APWP (Fig. 9). The Middle Devonian pole of this study lends support to the proposed Early Devonian loop, as it falls on a track between the Early and Late Devonian poles. Likewise, if the Early Devonian loop is indeed a true feature of the North American APWP, then it supports the Middle Devonian pole from this study.

With Early, Middle and Late Devonian poles tentatively established, preliminary evaluation of absolute plate motion and paleogeographies of North America during the Devonian can be conducted. Gordan and others (1984) have shown that the shape of the APWP is defined by a series of small circle arcs separated by hairpin cusps (Fig. 9). The small circle arcs or APWP tracks represent constant plate rotation about a paleomagnetic Euler pole (PEP), while the cusps represent some break in constant plate motion, such as an orogenic event. The Early Devonian represents an obvious cusp in the APWP, and presumably

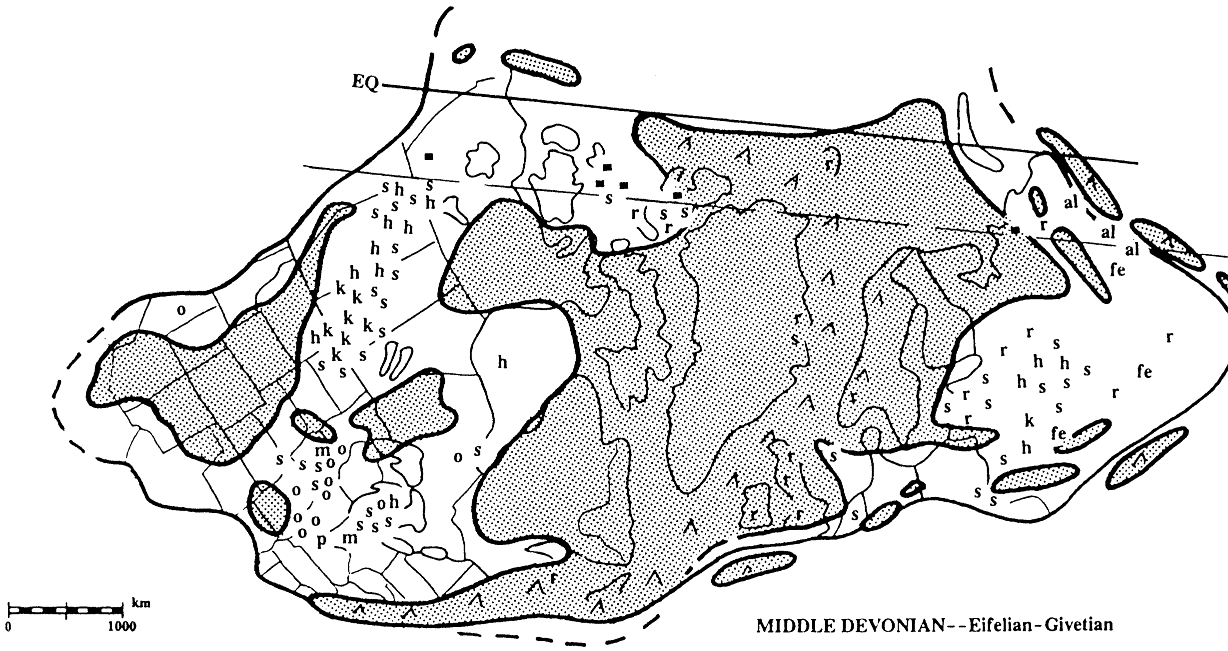


Figure 11. Middle Devonian paleolatitudinal reconstruction for North America as defined by Witzke, 1990.

corresponds to a change in plate motion as the Acadian Orogeny took place. Apparent polar wander between the Early and Late Devonian seems to follow a small circle track, and therefore probably indicates a time of constant plate motion for North America. While it is difficult to apply the PEP theory to the Paleozoic APWP with a high degree of confidence, the theory has been applied with greater confidence to the Cenozoic and Mesozoic.

Paleogeographies for plates are determined by calculating a pole of rotation about which the paleomagnetic pole is rotated to the present day pole. This is done by taking the cross-product between the two poles. The plate is then rotated about this rotation pole for an angular distance equal to the angular distance between the paleomagnetic pole and the present day pole. This rotation places the plate at the paleolatitude expected given the paleomagnetic polar coordinates. Paleolatitudinal reconstructions based on our Middle Devonian paleomagnetic pole place eastern Iowa at 12 south +/-9 (Fig. 10). Reconstructions based on paleoclimatic studies (Witzke, 1990) are similar, although paleolatitudes are estimated to be closer to the southern extent of our error range (Fig. 11).

A potentially related topic of research concerns the effects of meteorite impacts on the magnetization of the carbonates (Halls, 1979). By studying the interior craton, we have eliminated and/or substantially reduced the effects of deformation and related fluid migration associated with the Alleghenian Orogeny and resulting Permian overprint. However, because both study areas are located within 200 km (with some sites within 20 km) of an impact site (Manson impact in Iowa, K/T boundary; Lake Saint Martin impact in Manitoba, 225 +/- 40 ma), there exists the possibility that similar remagnetizations of the units may have occurred due to impact deformation. Although few studies have been conducted (Halls, 1979), shock remanent magnetizations (SRM) imparted almost contemporaneously with impact appear be the most likely type of remagnetization. Thermal and chemical remagnetizations may also be possible at very short distances from the center of impact. Halls (1979) found that as distance from the center of impact increased, a sharp decrease on the effects of rock magnetism resulted. Therefore, any attempts made to explain discordant sample directions by impact deformation will be limited to a small radius about the impact structure.

We propose that characteristic component B from Iowa, based on high latitudes of the calculated pole,

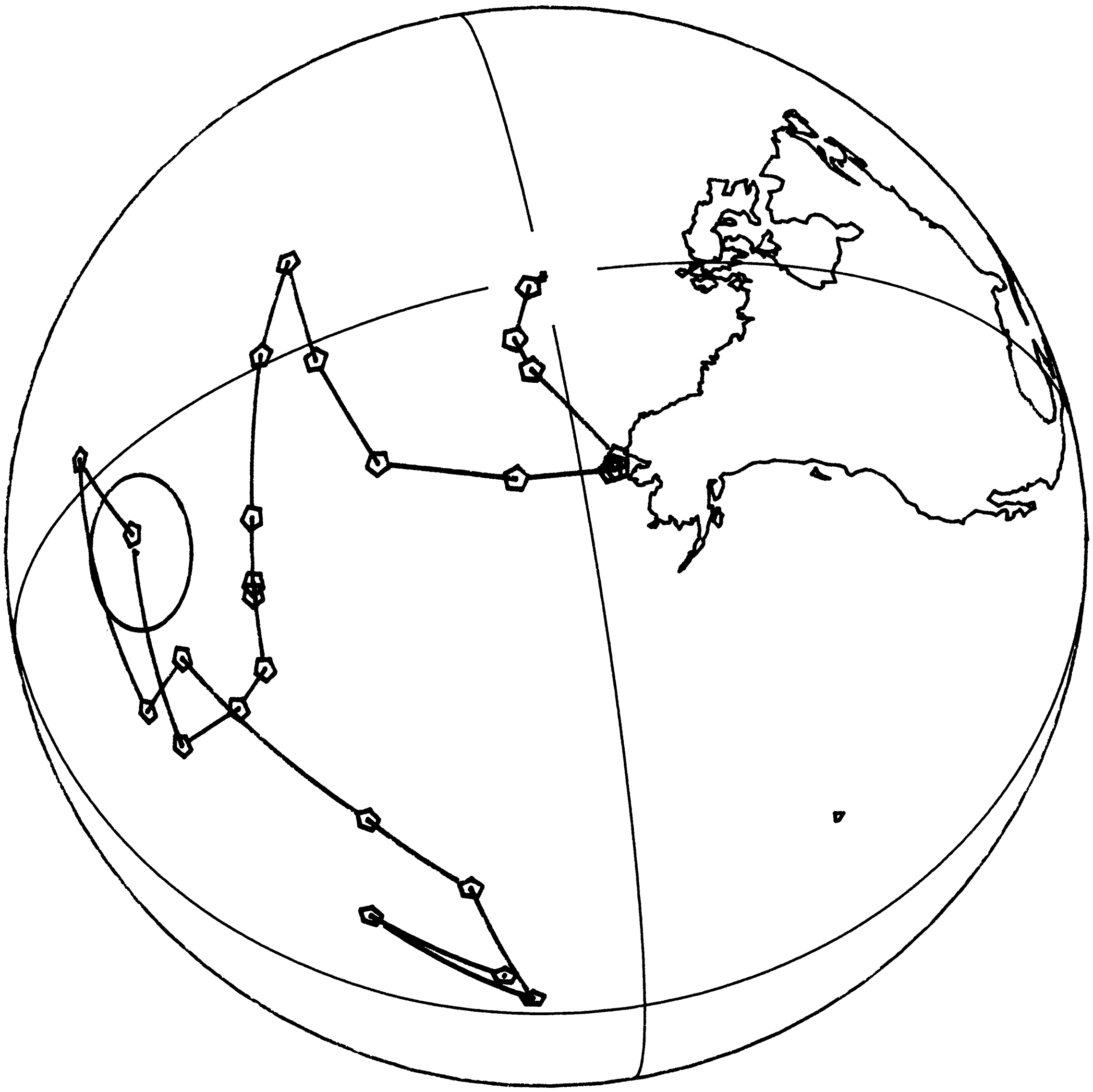


Figure 12. Oblique projection of the world plotting the mean Middle Devonian reference pole for North America averaged from the Iowa and Manitoba results. Symbols as noted in Figure 8.

may be a remagnetization event somehow associated with the Manson Impact at the Cretaceous/Tertiary boundary. Although this pole does not lie near the currently accepted position of a K/T boundary age pole, a study by Van Fossen (1991) discussed below suggests a swing in the APWP closer to a position near our pole calculated from the characteristic component B. Because site localities are up to 200 km from the impact site, the dynamics of the remagnetization event are uncertain at this point. Some of the odd components recorded in the Manitoba samples may also be the result of an impact-related remagnetization, although this is just speculation at this point.

UNCERTAINTY OF POLE DEFINITION

As discussed above, a certain degree of reservation must be placed in the evaluation of APWP records, as any reliable, discordant poles can bring an entire data base into question. A perfect example of this is the Middle Devonian pole, which until recently was believed to be well established (Kent and Opdyke, 1978). Of course this previous Middle Devonian pole has been reassigned as a Permian age magnetization, due to a better understanding of overprints and remagnetization processes (McCabe and Elmore, 1989; Lu et al., 1990). However, this leads to the question, just how reliable are other time periods for the North American APWP, even those now considered to be reliable?

Research recently published by Van Fossen (1991) has called into question the Middle Jurassic APWP record. While the current APWP is based mainly on studies from the southwest, Van Fossen generates questions about the paleomagnetic validity of each. Using transferred Middle Jurassic Gondwana poles and a Newark Basin pole, he finds evidence supporting a higher latitude Middle Jurassic pole than the one currently established. Alteration of the Mesozoic APWP will have drastic effects on paleomagnetic interpretations of absolute plate motion and paleoreconstructions. Whether or not Van Fossen's work proves to be accepted, it still has brought into question the entire Mesozoic data set, which is generally thought to be well defined.

Because of the uncertainties brought about by past alterations of the North American APWP, future revisions are surely to be expected, especially for weaker data sets. For this reason, a great deal of reservation must be placed in the evaluations and conclusions drawn from APWPs, as it has been shown that even the most reliable poles are subject to change

CONCLUSIONS

Based on the study of interior cratonic carbonate sequences, we present a mean Middle Devonian reference pole (Fig.12) averaged from the Iowa and Manitoba results; Lat=34.4N, Long=103.4E, a95=8.3, K=7.7. Three lines of evidence support our pole: close correlations between the Iowa and Manitoba results, paleoclimatic reconstructions, and preexisting Early and Late Devonian poles. Because of this, we believe we have established the first reliable Middle Devonian pole for North America. This helps to strengthen the underrepresented Mid Paleozoic paleomagnetic data base, which in turn provides a means to begin less tentative evaluation of the North American APWP.

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PART II

CEDAR VALLEY GROUP
PALEONTOLOGY AND BIOSTRATIGRAPHY

MIDDLE-UPPER DEVONIAN (LATE GIVETIAN-EARLY FRASNIAN) BRACHIOPOD SEQUENCE IN THE CEDAR VALLEY GROUP OF CENTRAL AND EASTERN IOWA

by

Jed Day
Department of Geography-Geology
Illinois State University
Normal, Illinois 61761

INTRODUCTION

This study focuses on the composition and biostratigraphy of the brachiopod faunas of the Little Cedar, Coralville, and Lithograph City formations of the Cedar Valley Group in central and eastern Iowa (Figs. 1, 2). Three new brachiopod zones are defined on the basis of the brachiopod sequence in the Little Cedar Formation (Fig. 3). Eighteen brachiopod faunas or associations are described from the Coralville and Lithograph City formations. Revisions to the stratigraphy and brachiopod zonation of Coralville and Lithograph City formations are included that are necessitated by new paleontologic and stratigraphic data collected since the studies by Day (1989a, 1989b). Knowledge of concurrent brachiopod and conodont ranges allows for the calibration of Cedar Valley Group brachiopod and conodont sequences (Fig. 3), which provides the basis for refined correlations of the late Givetian-Early Frasnian strata of the Iowa Basin with related successions throughout North America (Figs. 1, 3).

Four relative-sea-level events are recorded by strata of the Little Cedar, Coralville, Lithograph City, and Shell Rock formations of the Cedar Valley Group. Relationships between the Iowa Basin Devonian relative sea-level curve of Witzke et al. (1989) and the Euramerican Devonian sea-level curve of Johnson et al. (1985) and Johnson and Klapper (1992) are shown in Figure 3. Cedar Valley Group deposition was initiated by the Taghanic Onlap (Johnson, 1970), corresponding to T-R Cycle IIa (Devonian Depophase II) of Johnson et al. (1985). During periods of maximum transgression, widespread migration routes (open-marine cratonic seaway connections) were established between the Iowa Basin and other North American cratonic basins (Fig. 1).

The lower, transgressive, portions of Cedar Valley Group depositional sequences (Figs. 2, 3) are characterized by the influx of cosmopolitan species. Regressive phases of each relative sea-level cycle (Fig. 3) are characterized by: restriction or elimination of interbasinal cratonic seaway migration routes; reduction in overall geographic extent of shallow subtidal platform habitats; evolution of endemic taxa; and elimination of specialized taxa. Faunas of succeeding sequences are composed of carryover species, new endemic elements of lineages founded by older migrants, and new immigrants.

As many as 135 species, representing 49 genera (Tables 1-3) are known from late Givetian-early Frasnian age strata of the Little Cedar, Coralville, and Lithograph City formations. Initial taxonomic revisions outlined in Table 1 indicate that the fauna of the Little Cedar Formation consists at least 91 species representing 42 genera. The Little Cedar brachiopod fauna occurs in association with conodonts spanning the interval of the Middle *varcus* Subzone-Lower *subterminus* Fauna (Fig. 3; Klapper and Bunker, 1984, 1985; Witzke et al., 1989; Bunker, 1989; Johnson and Klapper, 1992).

The brachiopod fauna of the Little Cedar Formation (Table 1) is characterized by occurrences of important species of *Rhyssochonetes*, *Striatochonetes*, *Productella*, *Dichacaenia*, *Meristella*, *Echinocoelia*, *Charionella*, *Orthospirifer*, *Tylothyris*, *Eosyringothyris*, *Elita*, *Independatrypa*, *Neatrypa*, *Pseudoatrypa*, *Seratrypa*, *Spinatrypa* (*Spinatrypa*), *Hypothyridina*, and *Atribonium* (Fig. 2). Diverse, but largely endemic, species groups of *Strophodonta* (*Strophodonta*), *Pentamerella*, and *Cranaena* also serve to characterize the Little Cedar fauna (Table 1). Seventy-eight brachiopod species are restricted to the Little Cedar Formation. In the Iowa Basin (Figs. 1-3), fourteen (15%) Little Cedar species carry over into younger deposits of the Coralville Formation, Lithograph City Formation, or younger Frasnian units (Table 1). The extinctions of large numbers of brachiopod species in the interval corresponding to the Upper *hermanni*

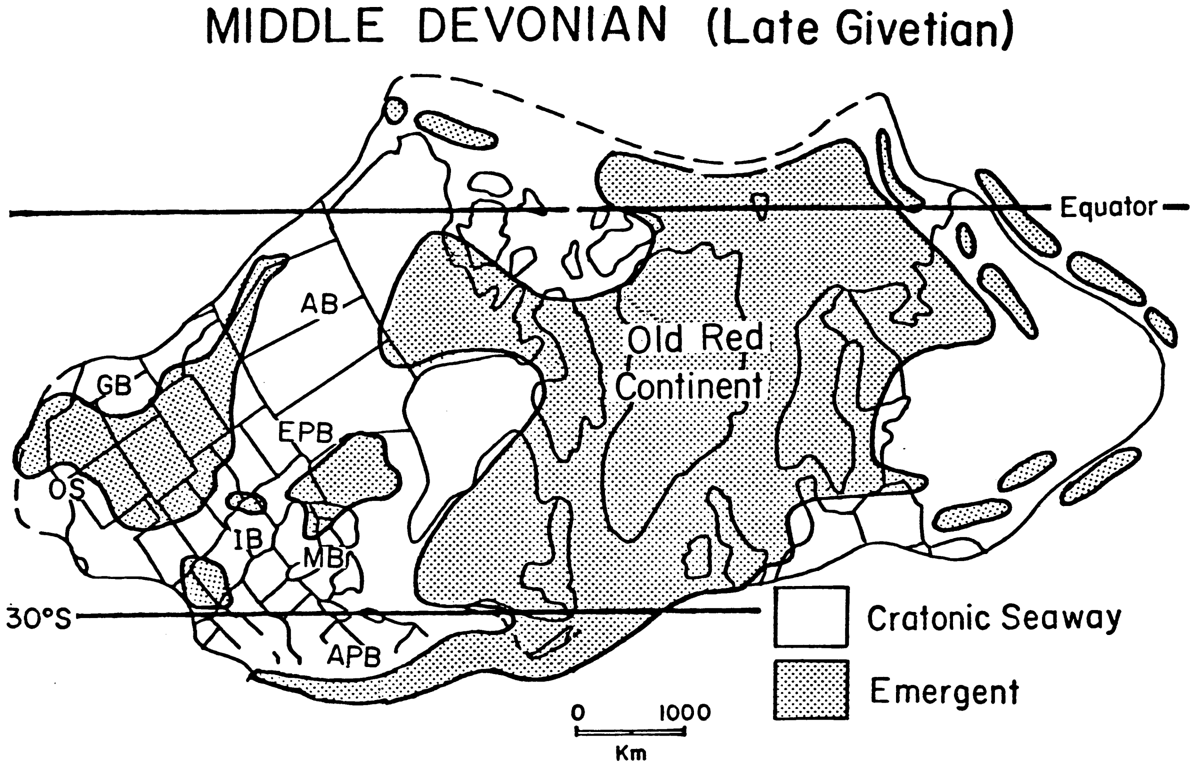


Figure 1. Middle Devonian (late Givetian) paleogeographic reconstruction of Euramerica showing extent of cratonic seaways established during the late Givetian sea-level rise of T-R Cycle IIa of Johnson et al. (1985), and locations of important Middle-Upper Devonian successions. Key: IB=Iowa Basin (Iowa, central and northeast Kansas, eastern Nebraska, central and northern Missouri); MB=Michigan Basin (lower Peninsula of Michigan, eastern Wisconsin), APB=Appalachian Basin, EPB=Elk Point/Williston Basins (southern Manitoba, north Dakota), OS=Oñate Seaway (southern New Mexico), GB=Great Basin (Nevada), AB=Alberta Basin. Modified from fig. 2b of Witzke & Heckel, 1989, fig. 5 of Day, 1990a.

Zone-Lower *disparilis Zone?* as seen in Iowa, mark a significant period of extinction of tropical, cratonic-platform, shallow-water benthic organisms in the Iowa Basin in the late Givetian, prior to the Frasnian-Famennian Mass Extinction. Similar extinction patterns at this time are noted in the records of tabulate and rugose corals (Pedder, 1977), and North American Givetian trilobite faunas (Hickerson, this guidebook).

The brachiopod fauna of the Coralville Formation consists of 28 species representing 21 genera (Table 2). Taxonomic revisions of generic or species nomens of Coralville brachiopod species identified in Day (1989a, 1989b) are summarized in Table 2 and discussed in later sections of this study. Most Coralville brachiopod taxa are Little Cedar carryovers, or elements of persistent species groups/lineages founded by Little Cedar ancestors (including *Athyris*, *Cranaena*, *Elita*, *Independatrypa*, *Pseudoatrypa*, *Pentamerella*, *Seratrypa*), or migrated into the Iowa Basin during the Coralville transgression (e.g. *Tecnocyrtina*). Brachiopod assemblages in strata of the lower part of the Coralville Formation (Table 2) occur in association with conodonts of the Upper *subterminus* Fauna (Fig. 3; Bunker, 1988; Witzke et al., 1989, Braun et al., 1989; Day et al., 1991). The Upper *subterminus* Fauna is taken to correlate with a position in the upper part of the *disparilis* Zone of the standard Givetian conodont sequence (Johnson et al., 1980, 1985; Witzke et al., 1989).

Strata of the Lithograph City Formation (defined by Bunker et al., 1986; Witzke et al. 1989) contain a

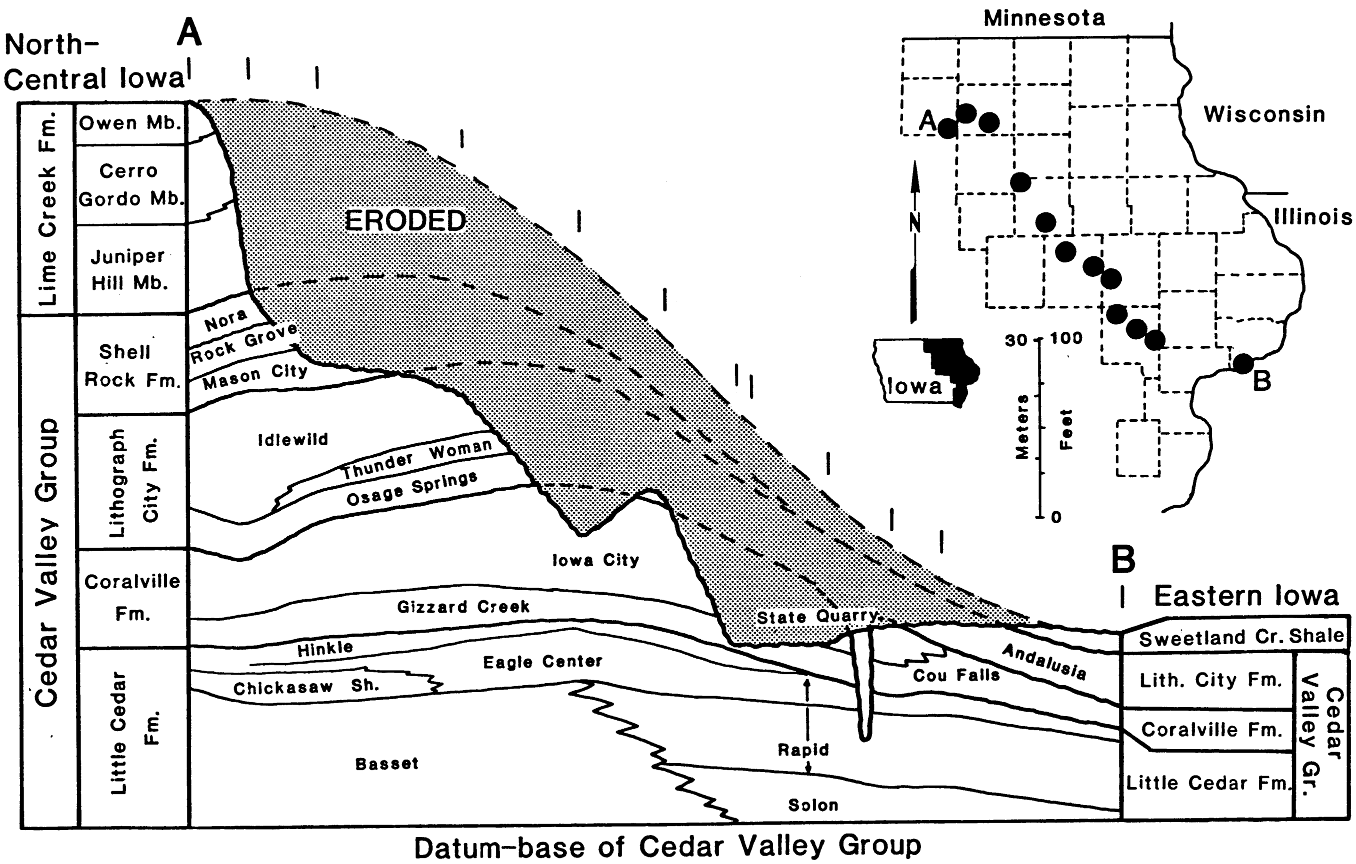


Figure 2. Generalized cross-section of the late Givetian and Frasnian strata of north-central and eastern Iowa. Only the Frasnian portion of the Sweetland Creek Shale is included in the sequence shown in extreme eastern Iowa (modified from fig. 1, Witzke et al., 1989; fig. 2 of Plocher & Bunker, 1989; after fig. 1 of Day, 1989a, fig. 3 of Day, 1989b).

brachiopod fauna of at least 29 species representing 19 genera (Table 3). Most notable of these are species of *Allanella, Cyrtina, Devonoproductus, Eleutherokomma, Eosyringothyris, Hadrorhynchia, Independatrypa, Pseudoatrypa, Spinatrypina, Schizophoria, Strophodonta* (*S.*), and *Tecnocyrtina*. Species of these genera occur in most parts of the the Lithograph City Formation in Iowa and its equivalents in Missouri ("upper Callaway Fm." of Witzke et al., 1989, and Snyder Creek Shale). The Lithograph City brachiopod fauna occurs in association with conodont faunas spanning the interval of the *norrisi* Zone (latest Givetian, see Klapper, *in* Johnson, 1990) through Zone 3 (early Frasnian) of the Frasnian conodont sequence in the Montagne Noire of southwestern France recently outlined by Klapper (1989).

The position of the Givetian-Frasnian (Middle-Upper Devonian) boundary within the Lithograph City Formation can not be established precisely because conodont faunas in the suspected interval lack diagnostic species of *Ancyrodella*, and are dominated by *Pandorinellina insita*. It is suggested here that this boundary be provisionally placed at a position corresponding to the base of the *Strophodonta* (*S.*) *callawayensis* Zone in the Andalusia Member in extreme eastern Iowa (Fig. 3).

LITTLE CEDAR FORMATION

In its type area in north-central Iowa, the Little Cedar Formation is divided into (in ascending order)

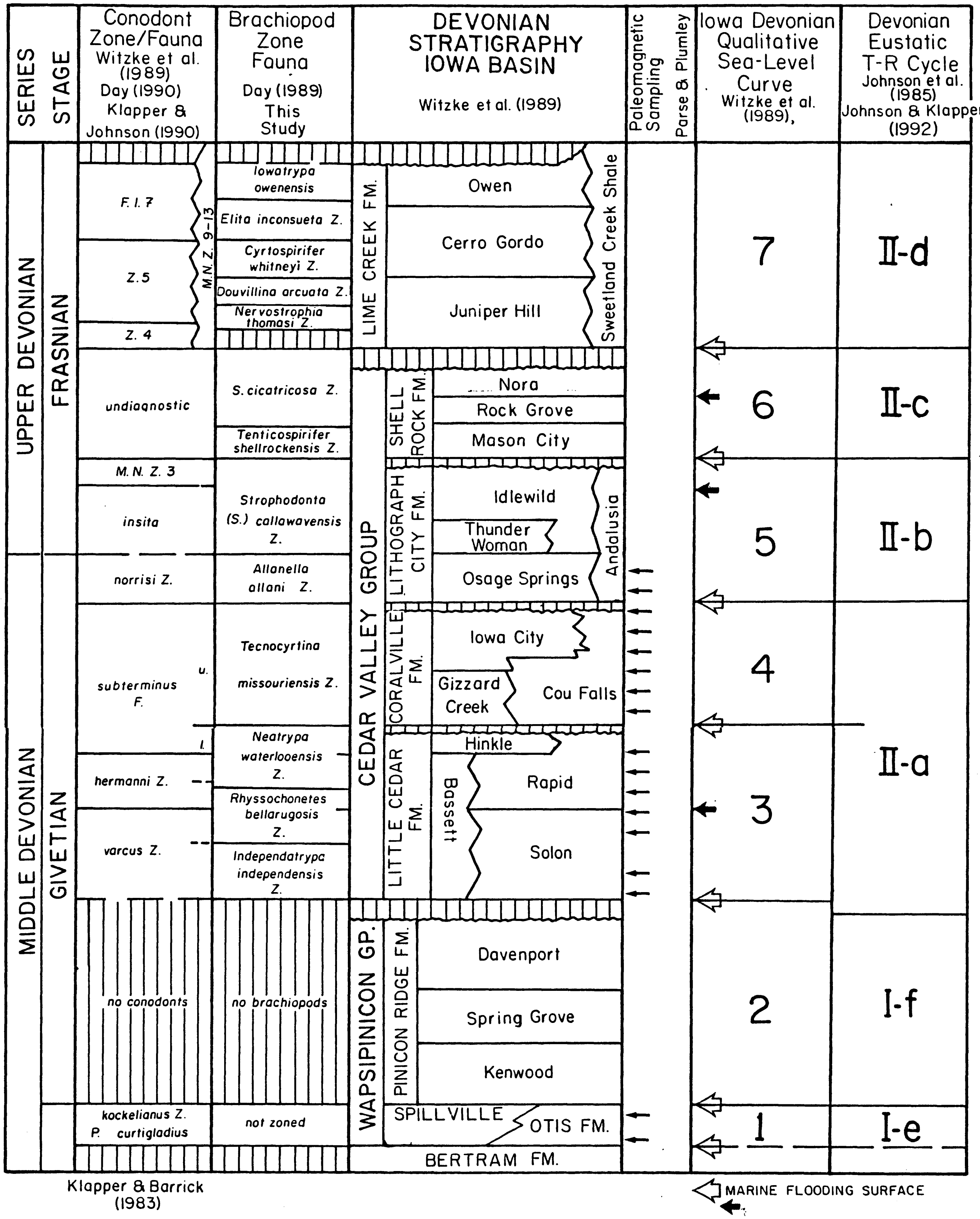

SERIES
STAGE
Conodont Zone/Fauna Witzke et al. (1989) Day (1990) Klapper & Johnson (1990)
Brachiopod Zone Fauna Day (1989) This Study
DEVONIAN STRATIGRAPHY IOWA BASIN
Witzke et al. (1989)
Paleomagnetic Sampling
Parse & Plumley
Iowa Devonian Qualitative Sea-Level Curve Witzke et al. (1989),
Devonian Eustatic T-R Cycle Johnson et al. (1985) Johnson & Klapper (1992)
UPPER DEVONIAN
FRASNIAN
MIDDLE DEVONIAN
GIVETIAN
F. I. 7
Z. 5
Z. 4
M.N. Z. 9-13
undiagnostic
M. N. Z. 3
insita
norrisi Z.
subterminus F.
u.
l.
hermanni Z.
varcus Z.
no conodonts
kockelianus Z.
P. curtigladius
Iowatrypa owenensis
Elita inconsueta Z.
Cyrtospirifer whitneyi Z.
Douvillina arcuata Z.
Nervostrophia thomasi Z.
S. cicatricosa Z.
Tenticospirifer shellrockensis Z.
Strophodonta (S.) callawavensis Z.
Allanella allani Z.
Tecnocyrtina missouriensis Z.
Neatrypa waterlooensis Z.
Rhyssochonetes bellarugosis Z.
Independatrypa independensis Z.
no brachiopods
not zoned
LIME CREEK FM.
Owen
Cerro Gordo
Juniper Hill
Sweetland Creek Shale
CEDAR VALLEY GROUP
SHELL ROCK FM.
Nora
Rock Grove
Mason City
LITHOGRAPH CITY FM.
Idlewild
Thunder Woman
Osage Springs
Andalusia
CORALVILLE FM.
Iowa City
Gizzard Creek
Cou Falls
LITTLE CEDAR FM.
Hinkle
Bassett
Rapid
Solon
WAPSIPINICON GP.
PINICON RIDGE FM.
Davenport
Spring Grove
Kenwood
SPILLVILLE
OTIS FM.
BERTRAM FM.
7
6
5
4
3
2
1
II-d
II-c
II-b
II-a
I-f
I-e
Klapper & Barrick (1983)
MARINE FLOODING SURFACE

Figure 3. (opposite page) Stratigraphic and biostratigraphic framework for the Middle and Early Upper Devonian (Eifelian-Frasnian) strata of the Iowa Basin, showing relationships between the qualitative Iowa Devonian sea-level curve of Witzke et al. (1989) and the Devonian eustatic sea-level curve of Johnson et al. (1985). Conodont zones in the Lime Creek Formation from Day (1990a), and Klapper (1990). Conodont faunas from the Wapsipinicon Group (Klapper & Barrick, 1983), Cedar Valley Group (up to 1987 summarized in Witzke et al., 1989; Kralick, this guidebook; this report), late Frasnian conodont sequences in the Lime Creek Fm. (see Metzger, 1989, and Day, 1990a), and the Sweetland Creek Shale (Johnson & Klapper, 1992). Modified from fig. 10 of Witzke et al. (1989); fig. 2 of Day (1989a, 1989b, 1990a); and fig. 12 of Johnson et al. (1985). Brachiopod biostratigraphy from Day (1989a, 1989b) and this report.

Table 1. Brachiopod fauna of the Little Cedar Formation of eastern Iowa. Compiled from Owen (1852), Hall (1857, 1867), White (1862), Meek & Worthen (1868), Hall & Whitfield (1872), Barris (1878), Whitfield (1880), Cleland (1911), Webster (1921), Branson (1922), Fenton & Fenton (1928, 1930, 1935), Cooper & Cloud (1938), Stainbrook (1938a, 1938b, 1940a, 1940b, 1941b, 1942, 1943a, 1943b, 1950), Griesemer (1967), Copper (1973, 1978), Pitrat (1977), Rogers & Pitrat (1987), Day (1989a, 1989b); Calvin, Stainbrook, and Belanski collections (SUI Repository, Univ. of Iowa), the author's collections, and collections of the IDNR-Geological Survey Bureau. Stainbrook's (1935, 1941a) faunal divisions of the Solon and Rapid Members in eastern Iowa (Fig. 5): lower-middle Solon Mb.= *independensis* zone = (l.-m.S.M.), upper Solon Mb. = *Profunda* zone = (u.S.M.), lower Rapid Mb.=*Atrypa bellula* zone = (l.R.M.), middle Rapid Mb. =*Pentamerella* zone = (m.R.M.), middle-upper Rapid Mb. = *waterlooensis* zone = (m.-u.R.M.), Eagle Center Mb. = E.C.M., Chickasaw Shale Mb. = C.S.M., Bassett Mb. = B.M. * = species ranging into the Coralville, and ** species ranging into the Lithograph City Formation. Species nomens preceeded by (=) are known or proposed synonyms. Species diversity=91 taxa.

Class-INARTICULATA	
Lingula milwaukeensis Cleland, 1911	(l.R.M.)
Lingulodiscina marginalis (Whitfield, 1880)	(S.M.-l.R.M.)
Orbiculoidea wardi Cleland, 1911	(m.-u.R.M.)
O. telleri Cleland, 1911	(l.R.M.)
Petrocrania famelica (Hall & Whitfield, 1872)*-**	(S.M.-l.R.M.)
Philhedra sheldoni (White, 1862)	(l.-m.S.M., l.R.M.)
Class-ARTICULATA, Order-ORTHIDA	
Rhipidomella cuneata (Owen, 1852)	(l.R.M.)
Schizophoria laudoni Stainbrook, 1940 *	(m.-u.R.M.)
S. meeki Fenton & Fenton, 1928	(l.-m.S.M.)
S. iowensis Hall, 1858	(l.R.M.)
Order-RHYNCHONELLIDA	
Atribonium gregeri (Branson, 1923)	(C.z.) Coralville
A. swallovi (Branson, 1923)	(u.S.M.)
Cupularostrum cedarensis (Stainbrook, 1942)	(m.-u.R.M., E.C.M.)
Hypothyridina intermedia (Barris, 1878)	(S.M.)
= *H. i. minor* Stainbrook, 1942	
Order-STROPHOMENIDA	
Devonochonetes calvini (Stainbrook, 1943)	(l.-m.S.M.)
Rhyssochonetes bellarugosis (Stainbrook, 1943)	(upp. l.-m.S.M., u.S.M.)
Striatochonetes buchananensis (Stainbrook, 1943)	(m.-u.R.M.)
S. schucherti (Cleland, 1911)	(l.R.M.)
Dichacaenia harberti (Stainbrook, 1943)	(l.R.M.)
Productella belanskii Stainbrook, 1943 *	(l.-m.S.M.)
P. linnensis Stainbrook, 1943	(u.S.M.)
P. subalata (Hall, 1857)	(m.-u.R.M.)
Stropholosia littletonensis Stainbrook, 1943	(m.-u.R.M.)
Protoleptostrophia fragilis (Hall, 1857)	(l.R.M., m.-u.R.M.)
= *Leptostrophia occidentalis* Stainbrook, 1943	
Schuchertella iowensis Stainbrook, 1943 *	(S.M.-R.M.)
Floweria? orthoplicata (Stainbrook, 1943)	(l.-m.S.M.)
Pholidostrophia iowensis (Owen, 1852) *	(S.M.)
Strophodonta quadratella Stainbrook, 1938	(m.-u.R.M.)
S. costata (Owen, 1852)	(l.-m.S.M.)

Table 1.--continued.

= *S. costata independensis* Stainbrook, 1938	
S. dorsata Stainbrook, 1938 **	(m.-u.R.M.)
Strophodonta solonensis Stainbrook, 1938	(S.M.)
S. umbonata Stainbrook, 1938	(l.R.M.)
S. (Strophodonta) cedarensis (Stainbrook, 1938)	(m.-u.R.M.)
S. (S.) halli (Cleland, 1911)	(l.R.M.)
S. (S.) linderi (Stainbrook, 1938)	(m.-u.R.M.)
S. (S.) littletonensis (Stainbrook, 1938)	(m.-u.R.M.)
S. (S.) parva (Owen, 1852) *	(m.R.M.)
S. (S.) *reticulata* (Stainbrook, 1938)	(u.S.M.)
S. (S.) subdemissa (Hall, 1857)	(l.S.M.)
Order-SPIRIFERIDA	
Athyris vittata Hall, 1860	(S.M.-R.M., E.C.M., B.M.)
(includes varieties *A. v. brandonensis*,	
A. v. randalia Stainbrook, 1942) *-**	
A. zonulata Stainbrook, 1942	(S.M.)
Charionella nortoni Stainbrook, 1942	(u.S.M.)
Meristella parva Cooper & Cloud, 1938	(u.S.M.)
Independatrypa independensis (Webster, 1921)	(S.M.-R.M.)
=*Atrypa expansa* Webster, 1921	
=*A. independensis janesvillensis* Fenton & Fenton, 1935	
Neatrypa brandonensis (Stainbrook, 1938)	(m-u R.M.)
Neatrypa trowbridgei (Fenton & Fenton, 1930)	(m-u R.M.)
Neatrypa waterlooensis (Webster, 1921) *	(m-u R.M., E.C.M.)
=*Atrypa gigantea* Webster, 1921	
=*A. waterlooensis websteri* Fenton & Fenton, 1930	
=*A. iowensis* Fenton & Fenton, 1935	
Neatrypa pronis (Fenton & Fenton, 1935)	(u.R.M.)
=*Atrypa pronis onusta* Fenton & Fenton, 1935	
Pseudoatrypa blackhawkensis (Stainbrook, 1938)	(E.C.M.)
P. bremerensis (Stainbrook, 1938)	(S.M.)
=*Atrypa littletonensis* Fenton & Fenton, 1930	
P. bentonensis (Stainbrook, 1938)	(l.-m.R.M.)
=*Atrypa devoniana tenuicosta* Stainbrook, 1938	
Seratrypa rustica (Stainbrook, 1938)	(S.M.)
Seratrypa brandonensis (Stainbrook, 1938)	(E.C.M & R.M.)
Spinatrypa (Spinatrypa) bellula (Stainbrook, 1938)	(l.R.M.)
S. (S.) mascula (Stainbrook, 1938)	(S.M.)
S. (S.) occidentalis (Hall, 1858)	(S.M.)
Cyrtina triquetra (Hall, 1858) *	(u.S.M.-R.M.)
C. umbonata (Hall, 1858) *	(m.-u.R.M.)
Elita subundifera (Meek & Worthen, 1868)	(l.R.M.)
E. minor (Stainbrook, 1940)	(l.-m.S.M.)
Echinocoelia halli (Branson, 1923)	(u.S.M.)
Eosyringothyris aspera (Hall, 1858)	(l.R.M.)
E. *thomasi* Stainbrook, 1943	(m.R.M.)
E. triangularis Stainbrook, 1943	(m.-u.R.M.)
=*E. calvini* Stainbrook, 1943	
Orthospirifer iowensis (Owen, 1852)	(S.M.-R.M.)
=*O. cedarensis* (Owen, 1952)	
=*O. brandonensis* (Stainbrook, 1943)	
Orthospirifer euruteines (Owen, 1844) *	(m.R.M.)
O. parryanus (Hall, 1858)	(l.-m.R.M., E.C.M.)
Tylothyris bimesialis (Hall, 1858)	(m.S.M.)
T. inultilis (Hall, 1858)	(l.-m.S.M.)
T. megista Stainbrook, 1943	(m.R.M.)
T. subattenuata (Hall, 1858)	(l.-m.S.M.)
T. subvaricosa (Hall & Whitfield, 1872)	(S.M.-R.M., E.C.M.)
=*T. randalia* Stainbrook, 1943	
Order-PENTAMERIDA	
Gypidula comis (Owen, 1852)	(S.M.)
G. occidentalis (Hall, 1858)	(m.S.M.)
Pentamerella magna Stainbrook, 1938	(m.R.M.)
P. rugosa Stainbrook, 1938	(m.R.M.)

Table 1.--continued.

P. subarata Stainbrook, 1938	(l.R.M.)
P. multicostella Cleland, 1911	(l.-m.S.M.)
P. laeviuscula (Hall, 1867) *	(u.S.M.)
P. obsolescens Hall, 1867	(u.S.M.)
Order-TEREBRATULIDA	
Cranaena subglobosa Stainbrook, 1941	(u.S.M.)
C. inflata Stainbrook, 1941	(l.R.M.)
C. littletonensis Stainbrook, 1941	(m.-u.R.M.)
C. romingeri (Hall, 1863)	(u.S.M.)
C. elia (Hall, 1867)	(u.S.M.)
C. jucunda (Hall, 1867)	(u.S.M.)
C. arcuosa Stainbrook, 1941	(u.S.M.)
C. subcylindrica Cooper & Cloud, 1938	(u.S.M.)
C. thomasi Stainbrook, 1941	(l.-m.S.M.)
Rensselandia cordiforme Stainbrook, 1941	(u.S.M., B.M.)
R. johanni Hall, 1867	(u.S.M., B.M.)

Table 2. Brachiopod fauna of the Coralville Formation. Taxa first appearing in the Coralville Formation are indicated by *, those ranging into younger strata of the Lithograph City Formation are indicated by **. Occurrence Key: lCF=*Cranaena* Zone of Stainbrook, uCF=Idiostroma Beds of Cou Falls Member, LC=lower Cou Falls Member-Buffalo Quarry, Scott County, UC=Upper Cou Falls Mb. Bufflao Quarry; IC=Iowa City Mb., GC=Gizzard Creek Mb. (modified from tables 1 of Day, 1989a, 1989b). Species diversity=28 taxa.

Class-INARTICULATA					
Petrocrania famelica (Hall & Whitfield, 1873)				LC	
Class-ARTICULATA, Order ORTHIDA					
Schizophoria laudoni Stainbrook, 1940		lCF		LC	
Order-STROPHOMENIDA					
Pholidostrophia iowensis (Owen, 1852)		lCF			
Productella? belanskii Stainbrook, 1943		lCF			
Schuchertella iowensis Stainbrook, 1943		lCF			
Strophodonta plicata (Hall) *		lCF			
= *S. occidens* (Hall, 1860)		lCF			
S. (S.) parva (Owen, 1852)		lCF		LC	
S. (S.) randalia (Stainbrook, 1943) *		lCF		LC	UC
Order-RHYNCHONELLIDA					
Atribonium subovata (Savage, 1921) *		lCF		LC	
Order-SPIRIFERIDA					
Athyris vitatta Hall, 1860 **	uCF	lCF	GC	LC	UC
A. cedarensis Stainbrook, 1942	uCF				
Cyrtina triquetra (Hall, 1858)		lCF		LC	
C. umbonata (Hall, 1858)					UC
Elita johnsonensis (Stainbrook, 1938)		lCF			
E. urbana (Calvin, 1892)	uCF				
Eosyringothyris aspera (Hall, 1858)					UC
Orthospirifer euruteines (Owen, 1844)		lCF		LC	UC
Tecnocyrtina missouriensis missouriensis (Swallow, 1860) *			GC		
Tylothyris subvaricosa (Hall & Whitfield, 1872)		lCF		LC	
Independatrypa randalia (Stainbrook,1938)		lCF	GC	LC	UC
Neatrypa waterlooensis (Webster, 1921)		lCF		LC	
Pseudoatrypa minor (Stainbrook, 1938) *				LC	UC
Seratrypa rotunda (Stainbrook, 1938) *		lCF	GC	LC	UC
Order-PENTAMERIDA					
Pentamerella dubia Hall *		lCF			
P. laeviscula (Hall, 1867)		lCF			
P. nitida Stainbrook, 1938 *		lCF			
Order-TEREBRATULIDA					
Cranaena iowensis (Calvin) *	uCF	lCF		LC	
Cranaena subovata Savage, 1862			lCF		LC

Table 3. Brachiopod fauna of the Lithograph Formation of north-central and eastern Iowa. Occurrence Key: OS = Osage Springs Mb., I = Idlewild Mb., SQ = State Quarry Mb., A = Andalusia Mb., LCl = lower Lithograph City Fm. and LCu = upper Lithograph City Fm. at the Garrison Quarry (STOP 1 this guidebook). First occurrence of species in the Lithograph City designated by *, species ranging into the Shell Rock Formation designated by **. Modified from tables 2 of Day (1989a, 1989b). The symbol n. sp.= undescribed species. Species diversity=30 taxa.

Class-INARTICULATA					
Lingula sp. cf *L. milwaukeensis* Cleland, 1911			SQ	A	
Class-ARTICULATA, Order-ORTHIDA					
Schizophoria lata Stainbrook 1940 *	OS	I	SQ	A	LCl
Order-RHYNCHONELLIDA					
Hadrorhynchia solon (Thomas & Stainbrook, 1921) *			SQ	A	
Order-STROPHOMENIDA					
Devonoproductus reticulocostus Norris, 1983 *			SQ		
Floweria altirostris (Stainbrook & Ladd, 1922) *	OS		SQ	A	
F. n. sp. of Day (1989a, 1989b) *			I		
Productella sp. cf. *P. fragilis* Belanski, 1928 *-**		I			
Strophodonta (*S.*) *inflexa* (Swallow, 1860) *			I		
S. (*S.*) *iowensis* (Stainbrook, 1943) *	OS		SQ	A	LCl
S. (*S.*) *callawayensis* (Swallow, 1860) *				A	
S. (*S.*) *scottensis* (Belanski, 1928) *-**		I			
Order-SPIRIFERIDA					
Allanella allani (Warren, 1944) *	OS	I	SQ		LCl-u
A. annae (Swallow, 1860) *				A	
A. n. sp. *		I			
Cyrtina sp. A (Norris, 1981) *			SQ	A	
=*Tecnocyrtina* sp. A of Norris (in Norris & Uyeno, 1981)					
=*Cyrtina triquetra* Hall, in Branson (1922)					
Orthospirifer capax (Hall, 1858) *			SQ	A	
Eleutherokomma n. sp. A. *			SQ		
E. n. sp. B *-**		I			
=*E. jasperensis* of Day (1989a)					
Eosyringothyris occidentalis Stainbrook, 1943 *			SQ	A	
Tecnocyrtina missouriensis n. ssp. *			SQ	A?	
Independatrypa scutiformis (Stainbrook, 1938) *			SQ	A	LCl
Pseudoatrypa rugatula (Stainbrook & Ladd, 1922) *			SQ		
=*Variatrypa rugatula* of Day (1989a, 1989b)					
Pseudoatrypa? *lineata* (Webster, 1921) *	OS	I			
=*Atrypa inflata* Webster, 1921					
=*Radiatrypa clarkei* of Day (1989a, 1989b)					
Spinatrypina (*Spinatrypina*) n. sp. *			SQ		
=*S.* sp. sf. *S. angusticostata* Johnson (in Day 1989a, 1989b)					
Athyris simplex Stainbrook & Ladd, 1922 *			SQ		
A. vittata Hall, 1860 **	OS	I		A	LCl-u
=*A. v. buffaloensis* Stainbrook, 1942					
Order-PENTAMERIDA					
Gypidulina n. sp. *		I			
Order-TEREBRATULIDA					
Cranaena depressa Stainbrook & Ladd, 1922 *			SQ		
C. infrequens Belanski, 1928 *	OS	I			
C. n. sp. *				A	LCu
MOLLUSCA AND CNIDARIA					
Class-BIVALVIA					
Paracyclus rowleyi (Branson, 1922)		I		A	LCu
Spathella sp. cf. *S. typica* Hall, 1885			SQ		
Class-GASTROPODA-ARCHAEOGASTROPODA					
Elasmonema n. sp.				A	
Class-ANTHOZOA-RUGOSA					
Tabulophyllum callawayense (Branson, 1922)			SQ	A	LCl

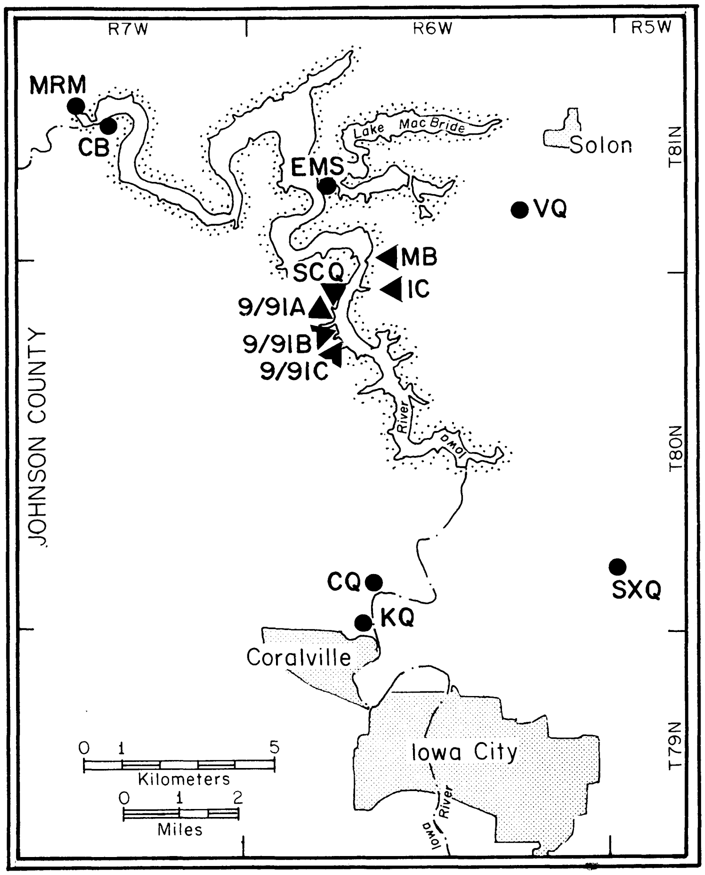


Figure 4. Map showing locations of important sections of Cedar Valley Group strata in the Johnson County area of eastern Iowa. Key: MRM=Mid-River Marina Quarry (STOP 3, Plocher et al., this guidebook); CB=Curtis Bridge (Plocher et al., this guidebook); EMS= Emergency Spillway (Plocher et al. 1989, p. 103-105); VQ=Vanourney Quarry (this study); MB=Mehaffey Bridge (Bunker & Witzke, 1987); IC= Indian Cave (Fig. 18, this study); SCQ=State Capitol Quarry (Watson, 1974; Bunker & Witzke, 1989: fig. 3 of Day, 1989a, fig. 4 of Day, 1989b); 9/91-A= section TS-4, fig. 15, Watson (1974); 9/91-B=section TS-5, fig. 15, Watson (1974), section 6, fig. 3, Bunker & Witzke (1989); 9/91-C=section 3, fig. 3, Bunker & Witzke (1989); CQ=Conklin Quarry (STOP 4, Witzke & Bunker, 1984; fig. 4, Plocher & Bunker, 1989; Fig. 5 of this study); KQ=Klein Quarry (Zawistowski, 1971; Kettenbrink, 1973), SXQ=Sixt Quarry, Rapid Creek (Rapid Member reference section).

the Bassett, Chickasaw Shale (where developed), Eagle Center, and Hinkle members (Fig. 2; Witzke et al., 1989; Bunker and Witzke, this guidebook). In eastern Iowa, the Little Cedar consists of the basal Solon and overlying Rapid members (Fig. 2). All members, except the Hinkle, contain brachiopod assemblages.

Little Cedar strata constitute a major cycle of marine deposition that was initiated by the largest eustatic sea-level rise of the Devonian (Figs. 1, 3), referred to as T-R Cycle IIa of Johnson et al. (1985) and Johnson and Klapper (1992). This sea-level event flooded the Iowa cratonic platform in the upper part of the Middle *varcus* Subzone (Fig. 3; Witzke et al. 1989; fig. 1, Johnson and Klapper, 1992). The timing of the beginning of T-R Cycle IIa also corresponds to initiation of major subsidence in the Illinois Basin and consequent foundering of the older late Eifelian-middle Givetian carbonate platform (Detroit River Group and its Hamilton equivalents) and the onset of black shale deposition in the Illinois Basin. In eastern Iowa, strata of the Solon Member record progressive deepening of the Little Cedar seaway. Maximum T-R Cycle IIa flooding is apparently represented by the lower part of the overlying Rapid Member (Witzke et al., 1989). In north-central Iowa, the Little Cedar transgressive facies are represented by skeletal dolomites of the Bassett Member; while overlying strata of the Chickasaw Shale, Eagle Center, and Hinkle members record progradation of inner platform subtidal and restricted-marine peritidal facies during regressive phases of Little Cedar deposition. Apparently, open-marine subtidal conditions prevailed for the duration of Little Cedar deposition southeast of the Hinkle edge (see Bunker and Witzke, this guidebook) in eastern Iowa, as recorded by strata of the Solon and Rapid members (Fig. 2).

Divisions of the Solon and Rapid members of the Little Cedar Formation are based on Stainbrook's (1935, 1941a) faunal zones as recognized in the main reference section of the Little Cedar Formation in Johnson County (loc. CQ, Fig. 4; Witzke et al., 1984, 1989) and are illustrated in Figures 5 and 6. The composite brachiopod sequence in the Little Cedar Formation (Fig. 6), compiled from the published litera-

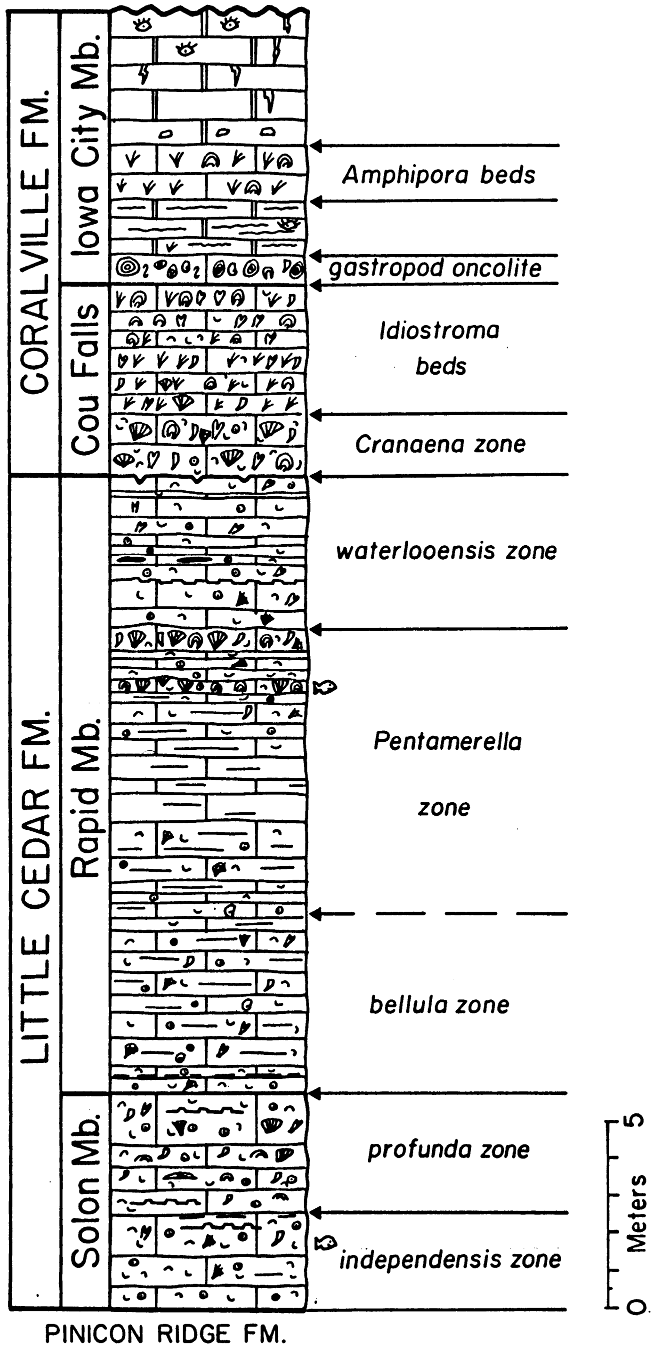


Figure 5. Reference section of the Little Cedar Formation in Johnson County at Conklin Quarry (locality CQ, Fig. 4). Stainbrook's (1935, 1941a) faunal subdivisions of the Little Cedar Formation correspond to divisions of the Little Cedar in Figure 6 as follows: *independensis* zone=lower Solon Member; *profunda* zone=upper Solon; *bellula* zone=lower Rapid Member; *Pentamerella* zone=middle Rapid; the *waterlooensis* zone=upper Rapid. (Modified from fig. 3 of Witzke & Bunker, 1984; fig. 4 of Plocher & Bunker, 1989; STOP 4).

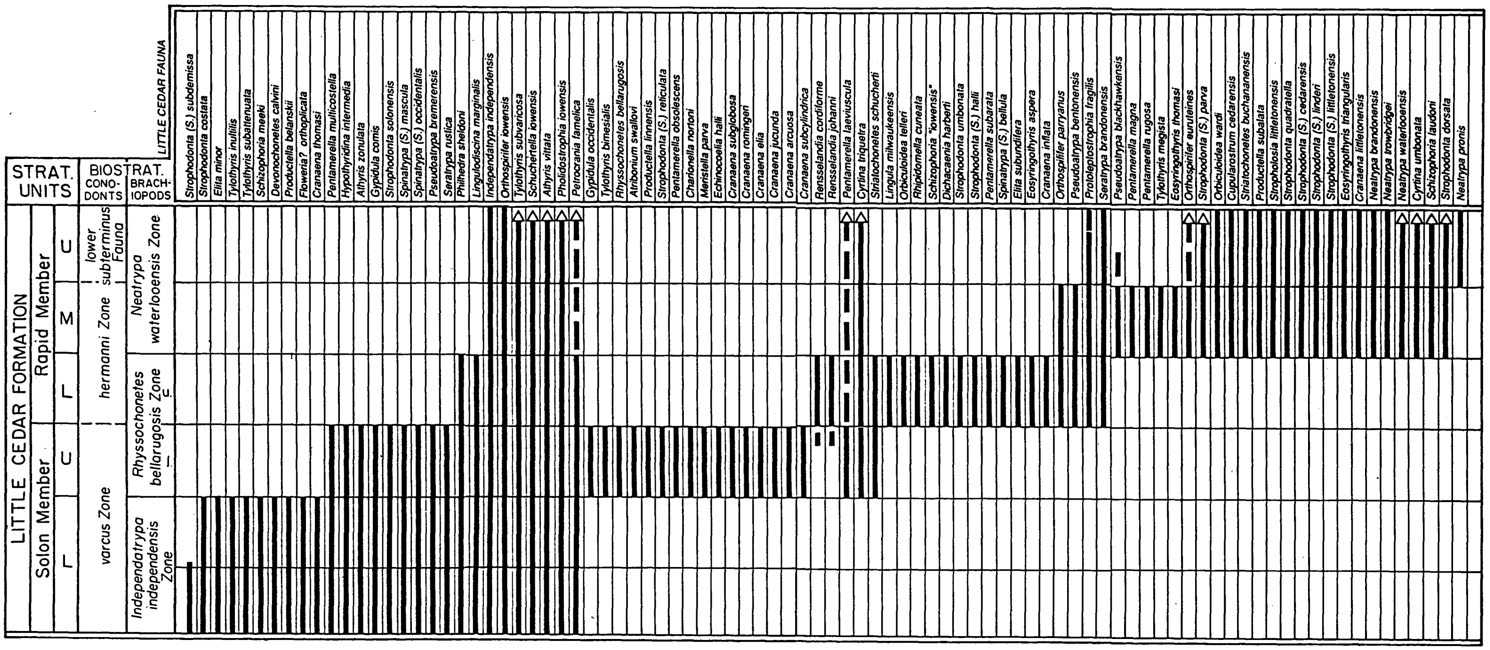


Figure 6. Composite brachiopod sequence in the Little Cedar Formation in the Johnson County area, eastern Iowa. The divisions of the Solon (lower and upper) and Rapid (lower, middle, upper) members are based on the faunal subdivisions of the aforementioned members, first proposed by Stainbrook (1935, 1941a), and adopted by Witzke & Bunker (1984, fig. 3) outlining the stratigraphic succession at Conklin Quarry (Fig. 5; STOP 4, fig. 1).

ture and faunal data resulting from recent studies by the author and members of the Geological Survey Bureau, must be considered provisional at this time. Ranges of many Little Cedar brachiopod taxa (Fig. 6) will be revised as species occurrences are better documented in future paleontologic studies of the Little Cedar Formation.

The Little Cedar fauna consists of at least 91 species and is one of the most diverse, abundant, and best illustrated late Givetian brachiopod faunas known from central and eastern North America. Seventy-eight of the 91 known Little Cedar species (Table 1, Fig. 6) are restricted to the Little Cedar sequence in the confines of the Iowa Basin. Brachiopod diversity (Fig. 6) in any one interval of the Solon or Rapid members ranges from 28-38 species. There appear to be a series of four major periods of range inceptions within the Little Cedar brachiopod sequence (Fig. 6). This pattern is probably in part an artifact of how the composite sequence was compiled, but does appear to detect sequential waves of faunal migration of cosmopolitan species into and through the Little Cedar seaway. Migration into the Iowa Basin was possible as the eustatic sea-level rise of T-R Cycle IIa (Fig. 3, Middle *varcus* Subzone) proceeded and extensive-diverse subtidal open-marine habitats became established throughout much of the cratonic interior of North America (Fig. 1). The apparent step-wise pattern of range inceptions (Fig. 6) may not only reflect successive waves of migration into the Iowa Basin, but also records successive speciation events in lineages of a number of brachiopod species groups. Most notable are species lineages of *Tylothyris*, *Elita*, *Eosyringothyris*, *Orthospirifer*, *Seratrypa*, *Pseudoatrypa*, *Cranaena*, *Pentamerella*, and *Strophodonta* (*Strophodonta*).

Previous Little Cedar Brachiopod Studies

All Little Cedar species listed in Table 1 (Fig. 6) have been described by previous workers. These include: Owen (1852), Hall (1857, 1867), White (1862), Meek and Worthen (1868), Swallow (1860), Hall and Whitfield (1872), Barris (1878), Whitfield (1880), Cleland (1911), Webster (1921), Branson (1923), Fenton and Fenton (1928, 1930, 1935), Cooper and Cloud (1938), Stainbrook (1938a, 1938b, 1940a, 1940b, 1941b, 1942, 1943a, 1943b, 1950), Greisemer (1965), Copper (1973, 1978), Pitrat (1977), Rogers and Pitrat (1987). Some Little Cedar taxa were first described from faunas of units in Missouri (Swallow, 1860; Branson, 1923, 1944; Gregor, 1936; Fraunfelter, 1967, 1974), and Wisconsin (Cleland, 1911; Griesemer, 1965). Stainbrook (ibid.) illustrated and described most of the brachiopod species known from the Little Cedar Formation (exceptions being Griesemer, 1965; Copper 1973, 1978; Pitrat, 1977; Rogers and Pitrat, 1987). Few of the type localities for brachiopod species originally described from the Little Cedar strata of Iowa are documented in the original publications.

Faunal Subdivisions of the Little Cedar Formation

Faunal divisions of the Little Cedar Formation were first outlined by Stainbrook (1935, 1941a), and are still used for informal division of the Little Cedar (Solon and Rapid members only) in the Johnson and Scott County areas of eastern Iowa (Fig. 5; Hickerson, this guidebook). Stainbrook (1935, 1941a) divided the Solon Member (Fig. 5) into the *independensis* zone (based on *Atrypa (=Independatrypa) independensis*), and an upper *profunda* zone (based on *Hexagonaria profunda*). The Rapid Member was divided into a lower *bellula* zone (after *Spinatrypa* (*S.*) *bellula*), a middle *Pentamerella* zone, and an upper *waterlooensis* zone (after *Neatrypa waterlooensis*). Stainbrook's "zones" conform to the concept of acme zones, and cannot be applied for the purposes of correlation outside of the Johnson, Linn, and (with limited application) Scott County region of eastern Iowa.

To avoid confusing workers outside of the U.S. midcontinent region accustomed to using Stainbrook's (1935, 1941a) faunal divisions of the Little Cedar Formation, I have retained (where possible) original names for brachiopod-based biozones (namely the *Independatrypa independensis* and *Neatrypa waterlooensis* Zones) defined on the basis of species range inceptions in the Little Cedar brachiopod sequence (Fig. 6). Little Cedar brachiopod zones are defined and discussed in the biostratigraphy section of this report.

Fauna of the Little Cedar in the Type Area Central Iowa

Witzke et al. (1989) revised the stratigraphy of the old Cedar Valley Limestone of Iowa, which previously included strata now assigned to the Little Cedar, Coralville, and Lithograph City formations (Figs. 2, 3). The type section of the Little Cedar Formation is located at the Chickasaw Park Quarry (p. 229, fig. 8C, Witzke et al., 1989) in southwestern Chickasaw County. Witzke et al. (1989) subdivided the type Little Cedar into the Bassett, Chickasaw Shale, Eagle Center, and Hinkle (where present) members. Facies relationships between members are shown in Figure 2. The first three members contain brachiopod faunas.

Bassett Member

Strata of the Bassett Member in central Iowa are equivalents of the Solon, and lower part of the Rapid Member of eastern Iowa (Witzke et. al., 1989). Witzke et al. (1989) described three divisions (lower, middle, and upper units) of the Bassett in its type area. The lower unit of the Bassett contains conodonts of the Middle-Upper *varcus* Subzone (Klug, 1982; Klapper and Barrick, 1983; Bunker, 1988; Witzke et al., 1989; Bunker and Witzke, this guidebook) and is correlated with the Solon Member of eastern Iowa. *Independatrypa independensis, Spinatrypa mascula, Orthospirifer iowensis, Productella subalata, Strophodonta* (*S.*) sp., *Cyrtina* sp., *Pentamerella* sp., and *Cranaena* sp. were listed by Witzke et al. (1989) from this unit.

The middle and upper units of the Bassett Member correlate with the lower and middle part of the Rapid Member of eastern Iowa (Figs. 2, 5). Conodont faunas from the lower and middle parts of the Bassett are not diagnostic of the *hermanni* Zone (Witzke et al., 1989; Bunker and Witzke, this guidebook). Species of *Rensselandia* (Stainbrook, 1941b) occur in the lower part of the middle unit of the Bassett at the Vinton Quarry in Benton County (Witzke et al., 1989; Bunker and Witzke, this guidebook). The brachiopod fauna of the middle and upper units of the Bassett are poorly known, although species of *Pseudoatrypa, Schizophoria, Cyrtina, Orthospirifer, Strophodonta* (*S.*), *Productella*, and *Pentamerella* are noted by Witzke et al., 1989).

Chickasaw Shale Member

The Chickasaw Shale Member overlies the Bassett Member in north-central Iowa, and is a facies equivalent of the lower part of the Eagle Center Member (Fig. 2). Both the Eagle Center and Chickasaw Shale members correlate with the upper part of the Rapid Member of eastern Iowa (Fig. 2; Bunker, 1988; Witzke et al., 1989; Bunker and Witzke, this guidebook). This unit is poorly fossiliferous, and shelly benthonic fossils are usually concentrated in thin shell lags. Large silicified *Neatrypa waterlooensis* make up virtually all skeletal material in shell lags in the upper 2.5 meters of this member in the Cerro Gordo Project Hole #1 (Fig. 2, locality A, logged by author, 1985). At this time, the fauna of this unit is poorly known, and in need of study.

Eagle Center Member

The Eagle Center Member, defined by Witzke et al. (1989), overlies the Bassett Member, or (where present) the Chickasaw Shale Member (Fig. 2). Brachiopods are typically scattered in burrowed, sparsely skeletal mudstone and wackestones that make up most of the unit, or are concentrated as major skeletal components of thin grainstone or packstone units (shell lags/storm deposits) in the Eagle Center (Fig. 7, Glory Quarry; Fig. 8, Garrison Quarry, STOP 1, this guidebook). Various brachiopod genera are listed from the Eagle Center Member in Bunker (1988), Witzke et al. (1989), and Bunker and Witzke (this guidebook).

At the Glory Quarry (Fig. 7), *Orthospirifer parryanus* and *Neatrypa waterlooensis* with rare *Tylothyris subvaricosa* occur in skeletal mudstone and wackestones (Fig. 7, units 1, 2, 4, upper half 5, lower half 6). Skeletal pack-and grainstones (Fig. 7, units 3, 5 (lower half)) contain assemblages dominated by abundant *Cupularostrum cedarensis*, with small numbers of large *Neatrypa waterlooensis, Tylothyris subvaricosa*, and *Athyris vittata*.

Brachiopods are not abundant in the Eagle Center Member at Garrison Quarry (Fig. 8; STOP 1, this guidebook), and tend to be scattered in mudstones, or occasionally form skeletal wackestones. The upper bed of unit 1 contains *Orthospirifer* sp. cf. *O. parryanus*, and skeletal wackestones and mudstones of unit 3 contain common *O.* sp. cf. *O. parryanus* with occasional *Pholidostrophia iowensis, Athyris vittata*, and large *Neatrypa waterlooensis*.

Fauna of the Little Cedar Formation in Eastern Iowa

The fauna of the Little Cedar Formation is best known from the Solon and Rapid Members in eastern Iowa. The following discussion of the Solon and Rapid faunas is based on the distribution of Little Cedar taxa in the reference section at Conklin Quarry (Fig. 5) and other Little Cedar sections in the Johnson County area of eastern Iowa (Figs. 4, 6).

Solon Member

At least 48 species of brachiopods occur in strata of the Solon Member in eastern Iowa (Fig. 6). Brachiopods are a very abundant in the Solon Member of eastern Iowa, faunas in any given interval are dominated by atrypids (*Independatrypa, Seratrypa, Pseudoatrypa, Spinatrypa* (*S.*), strophodontids (*Strophodonta* (*S.*)),

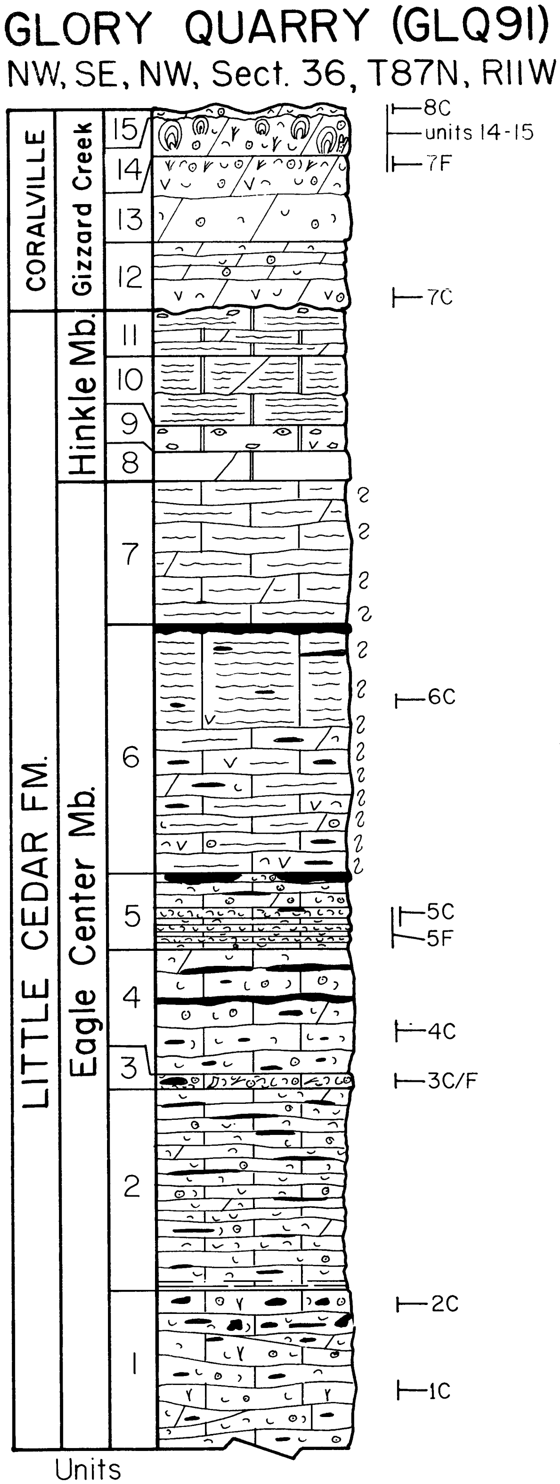


Figure 7. Measured section of the Devonian strata at Glory Quarry in southeast Blackhawk County, central Iowa. The section at Glory Quarry includes parts of the Little Cedar (Eagle Center and Hinkle members) and Coralville (Gizzard Creek Member) formations. Section location shown in Figure 8 (locality 6). Lithic and fossil symbols as in Figure 5. See Appendix for section description.

orthids (*Schizophoria*), and spiriferids (*Orthospirifer*, *Tylothyris*). Two waves of brachiopod migration into the Little Cedar seaway occurred during Solon deposition (Fig. 6), and provide the basis for distinguishing lower and upper Solon faunas.

Brachiopods of the Solon Member occur in association with conodont faunas of the *varcus* Zone. Conodont faunas place the base of the Solon in the upper part of the Middle *varcus* Subzone (Klapper and Ziegler, 1967; Bunker and Klapper, 1984; Witzke et al., 1985; Witzke et al., 1989; Johnson and Klapper, 1992), and probably also span the interval of the Upper *varcus* Subzone. The Upper *varcus* Subzone can not be recognized on the basis of the conodont faunas known from the upper part of the Solon Member (Witzke et al., 1989; fig. 1, Johnson and Klapper, 1992).

The brachiopod fauna in the lower Solon Member (*independensis* zone of Fig. 5) consists of 28 species and is characterized by the appearance of *Independatrypa independensis*, *Hypothyridina intermedia*, *Schizophoria meeki*, *Elita minor*, *Orthospirifer iowensis*, *Tylothyris inultis*, *T. subattenuata*, *T. subvaricosa*, *Spinatrypa* (*S.*) *mascula*, *Pseudoatrypa bremerensis*, and *Seratrypa rustica*. At least nine species appear to be restricted to the lower Solon, and include: *Strophodonta*(*S.*) *subdemissa*, *S. costata*, *Elita minor*, *Tylothyris inultis*, *T. subattenuata*, *Schizophoria meeki*, *Floweria*? *orthoplicata*, *Cranaenathomasi*, and the youngest species of *Devonochonetes* known in midcontinent and western North American faunas (*D. calvini*). Eighteen lower Solon brachiopods range into upper Solon or Rapid strata (Fig. 6). The brachiopod fauna in the upper half of the Solon Member consists of 38 species of which 18 are carryovers from the lower Solon interval (Fig. 6). Brachiopod taxa of the upper Solon fauna are elements of widely distributed species groups, and closely related species occur in the Tully Formation of New York (Cooper and Williams, 1935; Cooper, 1967; Johnson, 1970; Dutro, 1981; Cooper and Dutro, 1982), the Oñate Formation of New Mexico (Johnson, 1970; Cooper and Dutro, 1982; Day, 1988, 1989c), and the Dawson Bay

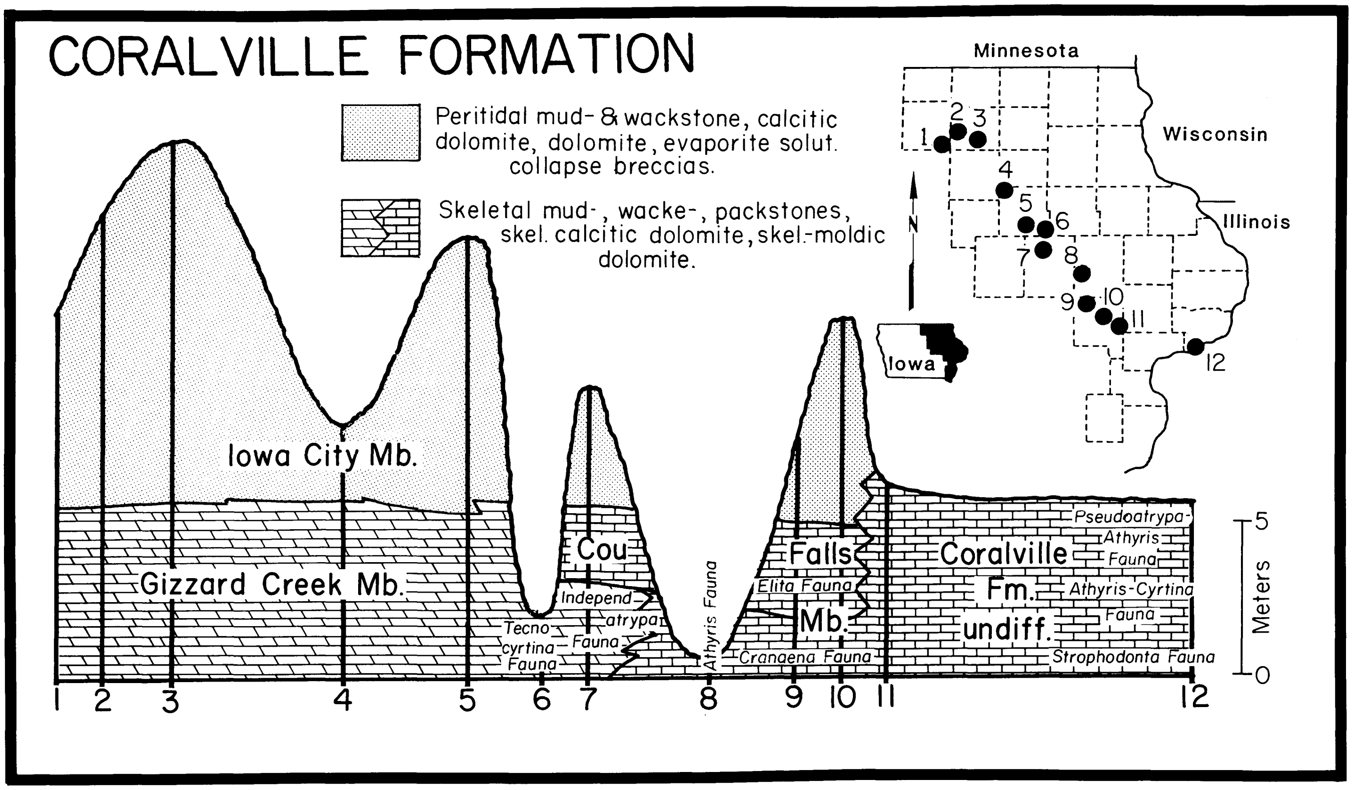


Figure 8. Generalized stratigraphy of the Coralville Formation in north-central and eastern Iowa. Locality Key: 1=Cerro Gordo Project Hole # 1, 2=Floyd-Mitchell Hole # 4, 3=Floyd-Mitchell Hole # 3, 4=Yokum Quarry, 5=Waterloo South Quarry, 6=Glory Quarry, 7=Garrison Quarry (STOP 1), 8=Palo Quarry (STOP 2), 9=Midriver Marina Quarry, 10=Conklin Quarry (STOP 4), 11=Mid-America Pipeline Well # 4, 12=Davenport Cement Company Quarry (=Buffalo Quarry, Fig. 10).

Formation of Manitoba (McCammon, 1960; Norris et al., 1982).

Of substantial importance to correlation of the Solon Member is the appearance of *Rhyssochonetes bellarugosis*, in association with *Hypothyridina intermedia*, *Striatochonetes shucherti*, *Atribonium swallovi*, *Charionella nortoni*, *Meristella parva*, and *Echinocoelia halli* in the upper Solon interval. All but *H. intermedia* are restricted to this interval of the Little Cedar. The upper Solon fauna is also distinguished by the occurrence of several species of the terebratulid genus *Cranaena* (Fig. 5). Stainbrook (1941b) indicated that species of the terebratulid *Rensselandia* (*R. cordiforme* and *R. johanni*) occur in the upper Solon interval. At this time, rensselanidids have been found in the uppermost Solon in Linn County, and the Bassett Member in Benton County (Witzke et al., 1989; Bunker and Witzke, this guidebook).

Rapid Member

The brachiopod fauna of the Rapid Member consists of at least 53 species (Fig. 5; 13 Solon Member holdovers) and is characterized by the first appearances of elements of widespread species groups, the most important being species of the atrypid genus *Neatrypa*, and the productellid *Dichacaenia*. There appear to be three major faunal divisions in the Rapid brachiopod sequence (Fig. 6) that provided the basis for earlier faunal divisions of the Rapid in eastern Iowa by Stainbrook (1935, 1941a, the *bellula* (lower Rapid), *Pentamerella* (middle Rapid), and *waterlooensis* (upper Rapid) zones) as shown in Figure 5.

Problems with Stainbrook's (1935, 1941a) faunal divisions of the Rapid become apparent, especially when considering the concept of the *waterlooensis* zone, supposedly demarked by the appearance of its name bearer (=*Neatrypa waterlooensis*). This species occurs first in the underlying interval of the *Pentamerella* zone (Figs. 5, 6). The only Little Cedar brachiopod with its first occurrence in the upper Rapid Member that could defone the base of the *waterlooensis* zone is *Neatrypa pronis* (Fig. 6).

The brachiopod fauna in the lower 4.5-5.0 meters of the Rapid Member consists of 30 species, 13 of these range up from Solon faunas. Important elements of the fauna in the lower Rapid include *Dichacaenia harberti*, *Spinatrypa* (*S.*) *bellula*, *Rhipidomella cuneata*, and *Seratrypa brandonensis*. Species apparently restricted to the "lower" Rapid fauna include: *Spinatrypa* (*S.*) *bellula*, *Rhipidomella cuneata*, *Strophodonta umbonata*, *S.* (*S.*) *halli*, *Elita subundifera*, *Pentamerella subarata*, *Orbiculoidea telleri*, *Cranaena inflata*, and *Eosyringothyris aspera*. The large terebratulids *Rennselandia cordiforme* and *R. johanni* occur in the Basset Member in central Iowa at a position thought to correspond to the uppermost Solon and lower Rapid interval in Johnson County.

The brachiopod fauna of the middle (=*Pentamerella* zone of Fig. 5) Rapid Member (Figs. 5, 6) consists of at least 36 species. Thirteen species that occur in the middle Rapid interval are carryovers from lower Rapid or Solon strata. The middle Rapid fauna is characterized by first occurrences of *Neatrypa waterlooensis*, with *Striatochonetes brandonensis*, *Cyrtina umbonata*, *Cupularostrum cedarensis*, *Orthospirifer euruteines*, *Strophodonta* (*S.*) *parva*, *Schizophoria laudoni*, and others shown in Figure 6.

Brachiopod assemblages of the upper Rapid Member consist of at least 32 species, with virtually all of these ranging up from older lower and middle Rapid strata (Fig. 6). The brachiopod fauna of the middle Rapid interval appears to record the last significant period of brachiopod migration into the Little Cedar seaway, where the upper Rapid fauna is composed of carryover taxa. The cessation of migration into the Iowa Basin was probably related to elimination of open-marine seaway connections during the regressive phase of Little Cedar deposition.

CORALVILLE FORMATION

The general stratigraphic relationships of the various members of the Coralville Formation are shown in Figures 2 and 8. Strata of the Coralville Formation represent T-R Cycle 4 of the Iowa Devonian sea-level curve, and the upper part of the Devonian eustatic T-R Cycle IIa of Johnson et al. (1985), and Johnson and Klapper (1992) as shown in Figure 3. In Johnson County (Figs. 5, 8), the Coralville is divided into the Cou Falls and Iowa City members (Witzke et al., 1989; Plocher and Bunker, 1989; Witzke and Bunker, this guidebook). The Cou Falls consists of subtidal open-marine skeletal carbonates representing the transgressive phase, and the restricted-marine peritidal carbonates of the Iowa City Member represent the regressive phase of Coralville deposition. In Scott County (Figs. 8-10), Cou Falls Member strata consist entirely of fossiliferous subtidal marine carbonates and minor shales. Cou Falls strata in Scott County are considered offshore equivalents of both the Cou Falls and Iowa City members in the Johnson County area, and the Gizzard Creek and Iowa City members in central and northern Iowa (Fig. 8).

All members of the Coralville Formation contain brachiopods, with 28 species known (Table 2, Fig. 9). Highest levels of brachiopod diversity in the Coralville are in strata of the Cou Falls Member in Johnson County where 20 species (Table 2, Fig. 9) occur in muddy coralline-stromatoporoid biostromal facies. Twelve Little Cedar brachiopod species range up into Coralville strata, with sixteen species making first appearances in the Coralville Formation.

Revisions to Coralville Brachiopod Identifications

Study of new and existing stratigraphic collections and type material of atrypids described by Stainbrook, Webster, and the Fentons (on loan to P. Copper, Laurentian University) necessitates changes to species identifications made by Day (1989a, table 1; 1989b, table 1). Day (ibid.) listed *Independatrypa independensis* from the Cou Falls and Gizzard Creek members of the Coralville in Iowa. The Coralville species of *Independatrypa* is *I. randalia* (Stainbrook, 1938)) and is the descendent of *I. independensis* (Webster, 1921). The latter species is restricted to the Little Cedar Formation in the Iowa Basin. *Atrypa rotunda* Stainbrook, 1938, was assigned to *Pseudoatrypa* Copper, 1973, by Day (1989a) and is reassigned here to *Seratrypa* Copper, 1967 (=*S. rotunda* (Stainbrook, 1938)). Copper (1967) attributed the Little Cedar atrypid *Atrypa rustica* Stainbrook, 1938 to *Seratrypa*, but did not assign the aforementioned Coralville species to the genus.

Schizophoria is common in the Cou Falls Member of the Coralville Formation, and was listed by Day (1989a, 1989b) as *S. lata* Stainbrook, 1940. The Coralville species of *Schizophoria* is most closely comparable to *S. laudoni* Stainbrook, 1940. The range of *S. lata* in Iowa and Canada is restricted to latest

CORALVILLE FAUNA	GIZZARD CREEK		COU FALLS MB.					
	Tecnocyrtina Fauna	*Independatrypa Fauna*	*Athyris Fauna*	*Cranaena Fauna*	*Elita Fauna*	*Strophodonta Fauna*	*Athyris-Cyrtina Fauna*	*Pseudoatrypa-Athyris Fauna*
Petrocrania famelica				●		●		
Schizophoria laudoni				●		●		
Atribonium subovata				●		●		
Pholidostrophia iowensis				●				
Productella belanskii				●	●			
Schuchertella iowensis				●				
Strophodonta plicata				●				
Strophodonta (S.) randalia				●		●	●	
Strophodonta (S.) parva						●	●	
Athyris vittata	●	●	●	●	●	●	●	●
Cyrtina triquetra				●		●		
Cyrtina umbonata						●	●	
Tecnocyrtina m. missouriensis	●							
Elita johnsonensis				●				
Elita urbana					●			
Eosyringothyris aspera				●				
Orthospirifer euruteines				●			●	
Tylothyris subvaricosa			●	●		●		
Independatrypa randalia	●	●		●		●	●	●
Neatrypa waterlooensis			●					
Pseudoatrypa minor				●		●	●	●
Seratrypa rotunda	●			●				
Cranaena iowensis			●	●	●	●		
Cranaena subovata						●		
Pentamerella laeviscula				●				
Pentamerella nitida				●				

Figure 9. Composition of brachiopod faunas described from the Coralville Formation (see Fig. 8), that correspond, in part, to Coralville brachiopod faunas described by Day (1989a, 1989b).

Givetian and early Frasnian age strata (no older than *norrisi* Zone).

Previous Faunal Divisions of the Coralville Formation

Stainbrook (1935, 1941a) outlined three faunal divisions within the Coralville Formation in the Johnson County area; these are in ascending order, the *Cranaena* zone, *Stromatopora* zone, and *Straparollus* beds. Strata included in the *Cranaena* and *Stromatopora* zones are now assigned to the Cou Falls Member (Witzke et al., 1989; Bunker and Witzke, this guidebook). Strata of the *Straparollus* beds correspond to the basal gastropod oncolite wackestones of the Iowa City Member in Johnson County (Fig. 5). Day (1989a, figs. 1, 4) described six brachiopod faunas from the Coralville Formation in Iowa, and defined the *Strophodonta plicata* Zone based on the brachiopod fauna of the Cou Falls Member. The brachiopod zonation of the Coralville Formation is emended here by definition of the *Tecnocyrtina missouriensis missouriensis* Zone (Fig. 3) to replace the *S. plicata* Zone (see biostratigraphy section).

Coralville brachiopod assemblages described by Day (1989a) include: the *Tecnocyrtina*, lower *Athyris*, *Cranaena*, *Elita*, *Strophodonta*, and upper *Athyris* faunas. Two additional faunas are described here (Figs. 8, 9) and include: the *Independatrypa* Fauna, based on the brachiopod fauna in the Gizzard Creek Member at the Garrison Quarry in Benton County; and the *Pseudoatrypa-Athyris* Fauna, based on the brachiopod fauna in the upper two meters of the Coralville at the Buffalo Quarry in Scott County (Figs. 10-12). Elements of the *Cranaena* Fauna, do not as implied by Day (1989a), occur in the Gizzard Creek Member of the Coralville at the Garrison Quarry in central Iowa.

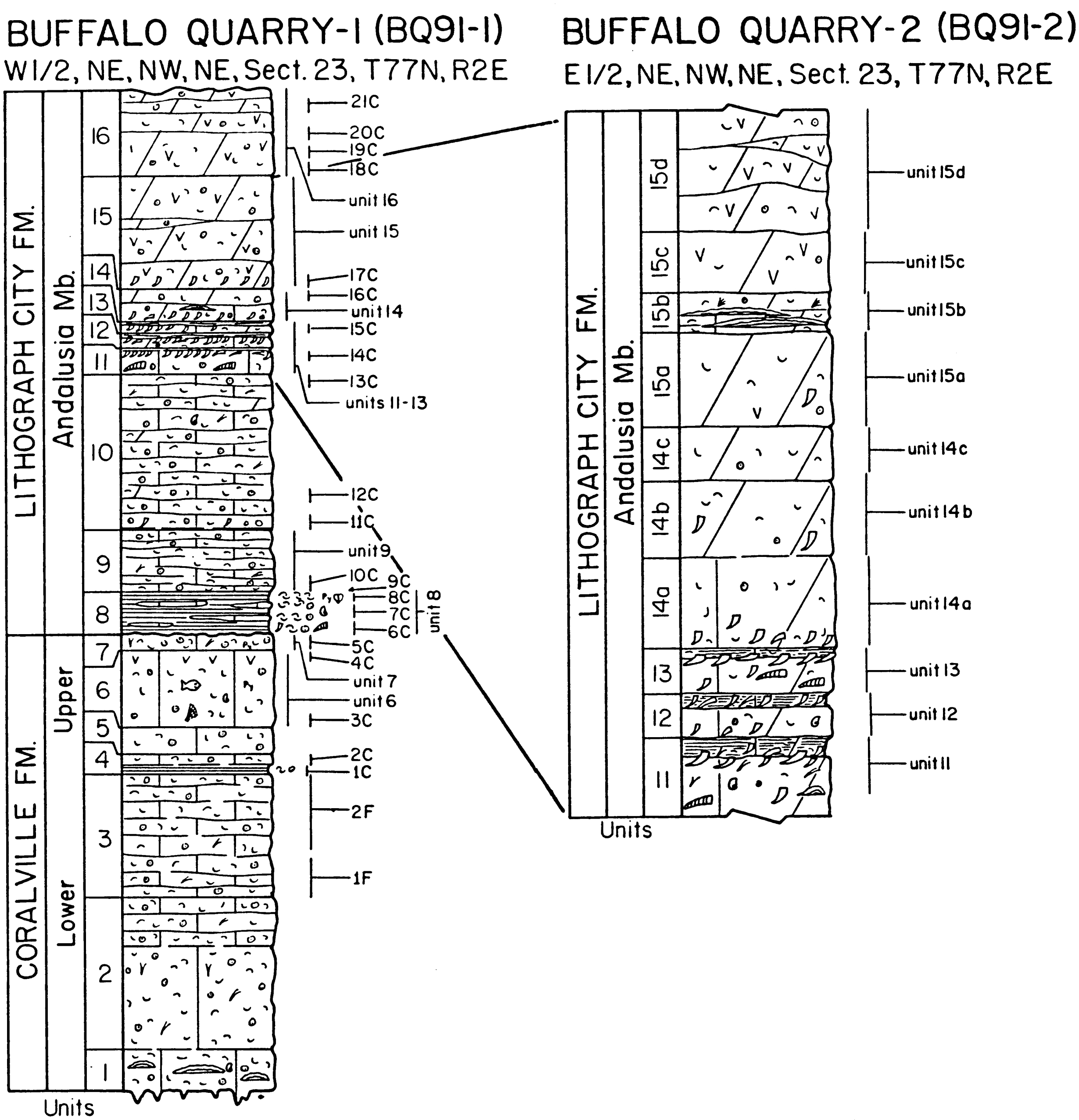


Figure 10. Stratigraphy of the Coralville and Lithograph City formations at Buffalo Quarry in Scott County, Iowa. Location of the Buffalo Quarry (=Davenport Cement Company Quarry) is shown in Figures 2 and 8. Lithic and fossil symbols as in Figure 5. See Appendix of this report for section descriptions.

BRACHIOPOD SEQUENCE IN THE CORALVILLE & LITHOGRAPH CITY FMS. BUFFALO QUARRY, SCOTT CO.

UNIT	CORALVILLE FM. Cou Falls Mb.								LITHOGRAPH CITY FM. Andalusia Mb.																		
ELEVATION	0.00	0.54	2.54	3.17	4.27	4.79	5.62	5.82	6.02	6.58	6.78	7.41	7.81	8.12	9.30	9.50	9.85	10.05	10.20	10.55	10.80	10.98	11.29	11.42	11.62	12.15	13.25
SAMPLE NUMBER	unit 1	unit 2	1F	2F	2C	3C	4C	5C unit 7	unit 8	10C	unit 9	11C	12C	point sample	13C	unit 11	unit 12	unit 13/15C	unit 14a	unit 14b	unit 14c	unit 15a	unit 15b	unit 15c	unit 15d	18C	21C
SAMPLE INTERVAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Athyris vittata	●		●	●			●												●			●	●				
Independatrypa randalia	●					●	●	●																			
Pseudoatrypa minor	●	●	●	●	●	●																					
Schizophoria laudoni	●																										
Orthospirifer euruteines		●	●	●																							
Strophodonta (S.) randalia		●		●		●	●																				
S. (S.) parva		●	●				●	●																			
Cyrtina umbonata		●	●																								
Tylothyris subvaricosa		●					●	●																			
Allanella annae									●		●		●														
Strophodonta (S.) iowensis									●		●				●												
Eosyringothyris occidentalis									●																		
Floweria n. sp.									●																		
Independatrypa scutiformis									●	●	●	●	●		●							●					
Schizophoria lata									●		●		●			●			●								
Orthospirifer capax										●	●			●	●						●						
Tecnocyrtina sp.										●																	
Cyrtina sp. A											●					●	●		●		●						
Strophodonta (S.) callawayensis																●	●	●	●	●	●	●	●	●	●	●	●
Aulopora sp.																●											
Allanella allani																●			●	●	●	●					
Tabulophyllum callawayensis									●							●	●	●	●	●		●					
Elasmonema sp.																	●										
Conocardium sp.																	●										
Cranaena n. sp.																	●		●				●				
Paracyclus rowleyi																				●							
Hadrorhynchia solon																							●				
BRACHIOPOD ZONE	*Tecnocyrtina m. missouriensis* Zone								*Allanella allani* Zone							*Strophodonta callawayensis* Zone											

Figure 11. Brachiopod sequence in the Coralville and Lithograph City formations at Buffalo Quarry, sample positions are shown in Figure 10, and detailed sample elevations are given descriptions of the Buffalo Quarry section in the Appendix. This chart also shows the occurrence of important species of the solitary tetracoral *Tabulophyllum callawayensis*, the archaeogastropod *Elasmonema* sp., and the bivalve *Paracyclus rowleyi.*

CONODONT SEQUENCE IN THE CORALVILLE & LITHOGRAPH CITY FORMATIONS: BUFFALO QUARRY, SCOTT CO.

Species / Sample	1C	2C	3C	4C	5C	6C	7C	8C	9C	10C	11C	12C	13C	14C	15C	16C	17C	18C	19C	20C	21C
Polygnathus sp.	●				●																
P. xylus xylus		●	●	●	●						●	●									
Icriodus subterminus	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●				
Polygnathus angustidiscus				●	●	●			●												
Mehlina gradata				●	●		●	●			●		●								
Pandorinellina insita						●		●	●	●	●	●	●	●	●	●	●	●	●	●	●
Polygnathus sp. C of Uyeno (1982)						●															
P. sp. cf. webbi								●		●									●		●
Ancyrodella africana																					●
Ancyrodella alata (late form)																					●
Ancyrodella rugosa																					●
Mesotaxis asymmetrica																					●
CONODONT ZONE/FAUNA	Upper *subterminus* Fauna					lower *P. insita* Fauna							upper						M.N. Zone 3		
STRATIGRAPHIC UNITS	Cou Falls					Andalusia Mb.															
	CORALVILLE					LITHOGRAPH CITY FM.															

Figure 12. Conodont sequence in the Coralville and Lithograph City formations at the Buffalo Quarry section, with sample positions shown in Figure 10, and precise sample elevations given in the Appendix. The occurrence of the *Ancyrodella-Mesotaxis* assemblage of sample interval 27 is the basis for correlation of the upper Andalusia Member with Zone 3 of the Frasnian conodont zonation of the Montagne Noire sequence (Fig. 3) of southwestern France by Klapper (1989), as discussed in Witzke et al. (1989), Day (1989a, 1990a), Johnson & Klapper (1992).

Age of the Coralville Formation

Strata of the lower open-marine facies of the Coralville Formation contain conodonts of the Upper *subterminus* Fauna (Figs. 3, 12; Witzke et al., 1985, 1989). Concurrent ranges of the brachiopods *Tecnocyrtina missouriensis missouriensis*, *Seratrypa rotunda*, *Cranaena iowensis*, *Strophodonta plicata*, *Independatrypa randalia*, and *Pseudoatrypa minor* with conodonts of the Upper *subterminus* Fauna provide the basis for correlation of the Coraville with coeval sequences in North America.

The Lower *subterminus* Fauna (=first appearance of *Icriodus subterminus*) occurs in the upper Rapid Member of the Little Cedar Formation (Fig. 2; Bunker, in Witzke et al., 1989). Conodonts of the Upper *subterminus* Fauna (lowest/first occurrences of *Mehlina gradata*, *Polygnathus angustidiscus*, with *I. subterminus*) consistently have their inceptions below strata of he Lithograph City Formation, contains conodonts of the *insita* Fauna (Figs. 3, 12). The Upper *subterminus* Fauna of the Coralville is taken to correlate with the Upper *disparilis* Subzone in Central Nevada (Johnson et al., 1980; Johnson et al., 1985) as discussed by Bunker and Klapper (1985), Bunker (in Witzke et al., 1989), Day (1989a, 1989b), and Day et al. (1991).

Brachiopod Faunas of the Coralville Formation

Coralville brachiopod faunas (Figs. 8, 9) correspond to different brachiopod biofacies that occupied various depositional regimes (restricted-marine, open-marine, distal subtidal shelf) of the Coralville seaway during the late Givetian. The *Cranaena*, *Elita*, and *Athyris* faunas of the Cou Falls Member in Johnson and Linn counties represent open-marine and subtidal middle shelf assemblages (Figs. 8, 9). The *Strophodonta*, *Athyris-Cyrtina*, and *Pseudoatrypa-Athryis* faunas of the Cou Falls Member in the Scott County area (Figs. 8, 9), represent distal subtidal shelf assemblages. Both the *Tecnocyrtina* and *Independatrypa* faunas of the lower Gizzard Creek Member in southeast Blackhawk and Benton counties, respectively, represent faunas that inhabited inner platform regimes of the Coralville seaway (Figs. 8, 9).

Cou Falls Member
Johnson and Linn Counties

Stainbrook (1938a-1943b) described most of the brachiopod species known from the lower Cou Falls Member and described this interval as the *Cranaena* zone owing to the abundance of *C. iowensis*. Day (1989a, 1989b) included brachiopod assemblages from Stainbrook's (1941a) *Cranaena* zone to characterize the *Cranaena* Fauna from the lower type Cou Falls Member. Brachiopod assemblages from the interval of the *Stromatopora* zone of Stainbrook (1941a), now called the *Idiostroma* Beds (Fig. 5; Glenister and Heckel, 1984), were the basis for characterization of the *Elita* Fauna by Day (1989a). In addition to the aforementioned faunas from the type Cou Falls, three additional brachiopod assemblages characterize different parts of the member in Scott County (Figs. 8, 9, 11), and are included in the *Strophodonta*, *Cyrtina-Athyris*, and *Pseudoatrypa- Athyris* faunas (Fig. 9).

***Cranaena* Fauna.** The brachiopod fauna in the lower part of the type Cou Falls Member (*Cranaena* zone of Stainbrook, 1935, 1941a) in the Johnson County area is called the *Cranaena* Fauna (Fig. 9; Day, 1989a, 1989b). The *Cranaena* Fauna consists of a diverse assemblage of brachiopods that occur in association with solitary and colonial tetracorals, tabulate corals, trilobites, bryozoans, domal stromatoporoids, echinoderms, gastropods, bivalves, and rostrochonchs. Numerically abundant species in this assemblage include *Cranaena iowensis*, *Pentamerella laeviscula*, *Strophodonta plicata*, *Seratrypa rotunda*, and *Pholidostrophia iowensis*. Additional brachiopods known to occur in the *Cranaena* Fauna include: *Neatrypa waterlooensis*, *Pseudoatrypa minor*, *Strophodonta (S.) parva*, *Pentamerella dubia*, *Atribonium subovata*, *Independatrypa randalia*, *Productella belanskii*, *Schuchertella iowensis*, *Tylothyris subvaricosa*, and *Orthospirifer euruteines*. *Strophodonta plicata*, *Atribonium subovata*, *Pentamerella dubia*, *Cranaena iowensis*, and *Seratrypa rotunda* are restricted to the lower part of the Coralville Formation in all Cou Falls sequences (Table 2) in Johnson and Linn counties, as well as in faunas at similar basal Coralville positions in central Iowa.

***Elita* Fauna.** The *Elita* Fauna (Fig. 9; Day, 1989a, 1989b) includes low and moderate diversity brachiopod assemblages that occur in association with tabulate corals and stromatoporoids in the old *Stromatopora* zone of Stainbrook (1941a), now referred to as the *Idiostroma* zone (Fig. 5; Table 2; Glenister and Heckel, 1984), of the upper part of the Cou Falls Member of the Coralville Formation in Johnson County. Brachiopod assemblages grouped in this fauna contain *Elita johnsonensis*, *Pentamerella laeviscula*, *Cranaena iowensis*, *Productella belanskii* (new occurrence) and *Athyris vittata*.

***Athyris* Fauna (revised).** The *Athyris* Fauna was originally described by Day (1989a) as the "Lower *Athyris* Fauna". This fauna occurs in the lower 0.45 meters of the Cou Falls Member at the top of the Devonian succession at Palo Quarry (Fig. 7; STOP 2). The Cou Falls at the Palo Quarry contains a low diversity brachiopod fauna dominated by *Athyris vittata*, with small numbers of *Tylothyris subvaricosa*, *Cranaena iowensis*, and *Neatrypa waterlooensis*, which occurs in association with branching and domal stromatoporoids. Occurrences of the latter three taxa provide the basis for correlation of this fauna with the *Cranaena* Fauna in Johnson County.

Cou Falls Member
Extreme Eastern Iowa

Stainbrook (1938b, 1943a, 1943b) subdivided the upper part of the "Cedar Valley Limestone" in Scott County into the "*Stropheodonta parva*" and overlying "*S. iowensis* " zones or zonules. Strata assigned to the *S. parva* zone are included in the Cou Falls Member (Fig. 10) and include the interval referred to by Udden (1899) as the "*Athyris vittata* beds" of the Cedar Valley (Fig. 10; Day, 1989a; Witzke et al., 1989). Strata of the "*Stropheodonta iowensis* zone" correspond to the Andalusia Member of the Lithograph City Formation (Fig. 10; Day, 1989a; Witzke et al., 1989).

Day (1989a) divided the Cou Falls Member in Scott County into lower and upper parts, with each division having distinctive brachiopod associations

(*Strophodonta* and Upper *Athyris* faunas, respectively). Recent study of the Devonian succession at the Davenport Cement Company Quarry at Buffalo (Fig. 10) has resulted in the elevation of the boundary between the Coralville and Lithograph City formations to a position two meters higher (Fig. 10, contact now at base of unit 8, formerly at base of unit 4) than in previous studies (Witzke et al., 1985; Witzke et al., 1989; Day, 1989a, 1989b). The new placement of the Coralville-Lithograph City contact is based on re-evaluation of brachiopod (Fig. 11) and conodont data (Fig. 12) reported here. Accordingly, a new brachiopod fauna is described from strata (units 4-7 of Fig. 10) formerly assigned to the lower part of the Andalusia Member of the Lithograph City Formation.

Three informal divisions of the Cou Falls Member (Fig. 10) are discussed here, each with distinctive brachiopod assemblages (Fig. 8). These are: 1. the lower (Fig. 10, units 1 and 2; =lower Coralville of Day, 1989a), 2. a middle (Fig. 10, unit 3, =upper Coralville of Day, 1989a; ="*Athyris vittata* beds" of Udden, 1899), and 3. the upper Coralville (Fig. 10, units 4-7; formerly included in Andalusia Member). The brachiopod assemblages from each of these subdivsions are described as the *Strophodonta*, *Athyris-Cyrtina* (="Upper *Athyris* Fauna" of Day, 1989a), and the *Pseudoatrypa-Athyris* faunas, respectively. Faunal diversity declines vertically within the Cou Falls Member in Scott County, Iowa (Fig. 11). The decline in brachiopod diversity (but not abundance) up-section may be an artifact of sampling, or could reflect restriction of conditions throughout most of the Coralville seaway as regression ended T-R Cycle IIa (Fig. 3; Johnson et al., 1985; Johnson and Klapper, 1992) deposition, and faunal migration into the Iowa Basin.

***Strophodonta* Fauna.** The *Strophodonta* Fauna (Figs. 8, 9) was described by Day (1989a) to include assemblages from the lower Cou Falls Member of the Coralville Formation at the Buffalo Quarry in Scott County (Fig. 10, units 1 and 2; Fig. 11, samples 1 and 2; = lower skeletal calcarenite unit of Witzke et al., 1985). The *Strophodonta* Fauna (Figs. 9, 11) is characterized by the occurrence of common *Strophodonta (S.) parva*, *S. (S.) randalia*, with *Cyrtina umbonata*, *Athyris vitatta*, *Independatrypa randalia*, *Pseudoatrypa minor*, *Tylothyris subvaricosa*, *Schizophoria laudoni*, *Atribonium subovata*, *Cranaena iowensis*, and *C. subovata*. This fauna correlates with the *Cranaena* Fauna of the Cou Falls Member in Johnson County, and the *Tecnocyrtina*, and *Independatrypa* faunas of the Gizzard Creek Member in Benton and Blackhawk counties (Fig. 8).

***Athyris-Cyrtina* Fauna (revised).** The *Athyris-Cyrtina* Fauna (Figs. 8, 9) is characterized by the occurrence of abundant *Athyris vitatta* and *Cyrtina umbonata* in unit 3 (Figs. 10, 11, samples 3 and 4) of the middle Cou Falls Member at the Buffalo Quarry. These species occur with *Strophodonta (S.) randalia*, *S. (S.) parva*, *Pseudoatrypa minor*, and *Orthospirifer euruteines*. Udden (1899) referred to these strata as the *Athyris vitatta* beds.

***Pseudoatrypa-Athyris* Fauna (new).** An abundant low-diversity brachiopod fauna occurs in association with echinoderms in units 4-7 (Figs. 9-11) in the upper Cou Falls Member at Buffalo Quarry. This fauna is characterized by the occurrence of abundant *Pseudoatrypa minor*, *Athyris vittata*, with smaller numbers of *Independatrypa randalia* (Fig. 9). Additional study of this interval will most likely produce additional taxa. The upper surface of unit 7 (Fig. 10) is a prominent hardground.

Iowa City Member

Most peritidal carbonates of the Iowa City Member in central and eastern Iowa are devoid of articulate brachiopods, although rare *Athyris vittata* occur (Witzke et al., 1989; Day, 1989a). This species occurs in the Iowa City Member at the Garrison Quarry in Benton County, and at various localities in the Johnson County region of eastern Iowa.

Gizzard Creek Member

The basal marine strata (largely dolomitized) of the Coralville Formation in central Iowa quarry exposures and the subsurface are placed in the Gizzard Creek Member (Figs. 7, 8; see Witzke and Bunker, this guidebook; STOP 1). Brachiopods are locally abundant in the Gizzard Creek with echinoderms, gastropods, and stromatoporoids in assemblages characterized by low diversity and high abundance. Day (1989a, 1989b) described the *Tecnocyrtina* Fauna from the Gizzard Creek Member in central Iowa (Figs. 7, 8, Glory Quarry). Recent study of Gizzard Creek strata at the Garrison Quarry (Fig. 7; STOP 1) provide the basis for description of the *Independatrypa* Fauna.

***Independatrypa* Fauna (new).** The *Independatrypa* Fauna is defined here to include brachiopod-dominated fossil assemblages in the Gizzard Creek Member at the

Garrison Quarry (Figs. 8, 9). This fauna is characterized by the occurrence of abundant moldic *Independatrypa randalia* with small numbers of *Athyris vittata* in the Gizzard Creek, underlying biostromal facies of the Cou Falls Member. This fauna occupies a position corresponding to the *Tecnocyrtina* Fauna in the lowermost Gizzard Creek in southeast Blackhawk County, the Lower *Athyris* Fauna in the Cou Falls Member in eastern Linn County (Palo Quarry), the *Cranaena* Fauna of the type Cou Falls in Johnson County, and the *Strophodonta* Fauna in the lower part of the Cou Falls in Scott County, Iowa (Fig. 8).

***Tecnocyrtina* Fauna (revised).** The original description of the *Tecnocyrtina* Fauna by Day (1989a) was based on fossil assemblages from the lower 1.9 meters of the Gizzard Creek Member at the Glory Quarry (Fig. 7, units 12-15) in southeast Blackhawk County (Figs. 8, 9). The *Tecnocyrtina* and *Independatrypa* faunas are similar (Fig. 9) in that *I. randalia* dominates numerically in both faunas, but differ in that *Athyris vittata* is also abundant with small numbers of *Tecnocyrtina missouriensis missouriensis* and *Seratrypa rotunda* in the *Tecnocyrtina* Fauna. Elements of the *Tecnocyrtina* Fauna occur in association with branching idiostromid and large (up to 20 cm) hemispherical and domal stromatoporoids (Fig. 7, unit 14). The occurrence of *Seratrypa rotunda* with *Independatrypa randalia* in this fauna allows direct correlation with the *Cranaena* Fauna of the Cou Falls Member in Johnson County.

The occurrence of *Tecnocyrtina missouriensis* (Swallow) in the Gizzard Creek Member, with conodonts of the Upper *subterminus* Fauna (Rogers, 1990), is of substantial stratigraphic significance for correlation of the Coralville Formation as a whole. This species was originally described (Swallow, 1860; Branson, 1922; Fraunfelter, 1974) from strata of the Callaway Formation of central Missouri. This species occurs in the "upper" Callaway (sensu Witzke et al., 1989) with conodonts of the *P. insita* Fauna. This species also occurs in the lower Snyder Creek Formation in central Missouri (Branson, 1924; Fraunfelter, 1967, 1974). In Canada, this species was recovered by the author in the lowermost beds of the Argillaceous limestone beds of the Point Wilkins Member of the Souris River Formation in southern Manitoba. Related species occur in the upper Denay Limestone in central Nevada (Johnson and Norris, 1972; Johnson and Trojan., 1982).

LITHOGRAPH CITY FORMATION

Strata of the type Lithograph City Formation in north-central Iowa are included in the Osage Springs, Thunder Woman Shale (where present), and the Idlewild members (Figs. 2, 13, 14). Type Lithograph City strata consist of a variety of open-marine and restricted-marine carbonate and clastic facies, deposited in inner shelf regimes of the Lithograph City seaway. The Lithograph City also includes strata placed in the State Quarry Member (Figs. 2, 15-18) in Johnson County, and the Andulusia Member in Scott County, Iowa (Figs. 10-12). The State Quarry Member in Johnson County (Figs. 15, 16, 18) consists of a variety of mud- and grain-supported skeletal carbonate lithofacies interpreted as a tidal channel and channel margin mudbank deposits. The Andalusia Member in extreme eastern Iowa (Figs. 10-12) consists of mud-rich skeletal carbonates, dolomites, and minor shales that accumulated in the distal-deeper parts of the Lithograph City seaway.

Strata of the Lithograph City Formation represent a single major depositional sequence (Figs. 2, 3) corresponding to T-R Cycle 5 of Witzke et al. (1989), and Devonian eustatic T-R Cycle IIb of Johnson et al. (1985) and Johnson and Klapper (1992). The IIb transgression (Fig. 3) established direct cratonic seaway connections between the Iowa Basin and the Michigan Basin, the Williston/Elk Point Basin of southern Manitoba (Souris River Fm), and central and northern Alberta (Waterways Fm). Areas of central and northern Missouri (Upper Callaway Fm. of Witzke et al., 1989; and Snyder Creek Fm), eastern Nebraska, and central and northern Kansas (Wapsipinicon and Cedar Valley groups, Day, 1990b) were contiguous with the Iowa Basin. Faunas in the foregoing regions are characterized by the occurrence of similar species of *Allanella, Cyrtina, Tecnocyrtina, Strophodonta (Strophodonta), Devonoproductus, Orthospirifer* (U.S. Midcontinent and Alberta), and *Schizophoria.*

The Lithograph City Formation (undifferentiated) section at the Garrison Quarry (STOP 1) in Benton County is of substantial stratigraphic and paleoenvironmental significance. This section helps to illustrate the major facies transition between inner platform regimes (area of type Lithograph City, Figs. 2, 13), and fully open-marine middle and outer platform regimes (State Quarry and Andalusia members) of east-central and extreme eastern Iowa. Marine fossils are common in various units of the Lithograph City Formation at Garrison Quarry and contain the brachiopods *Allanella allani, Athyris vittata,*

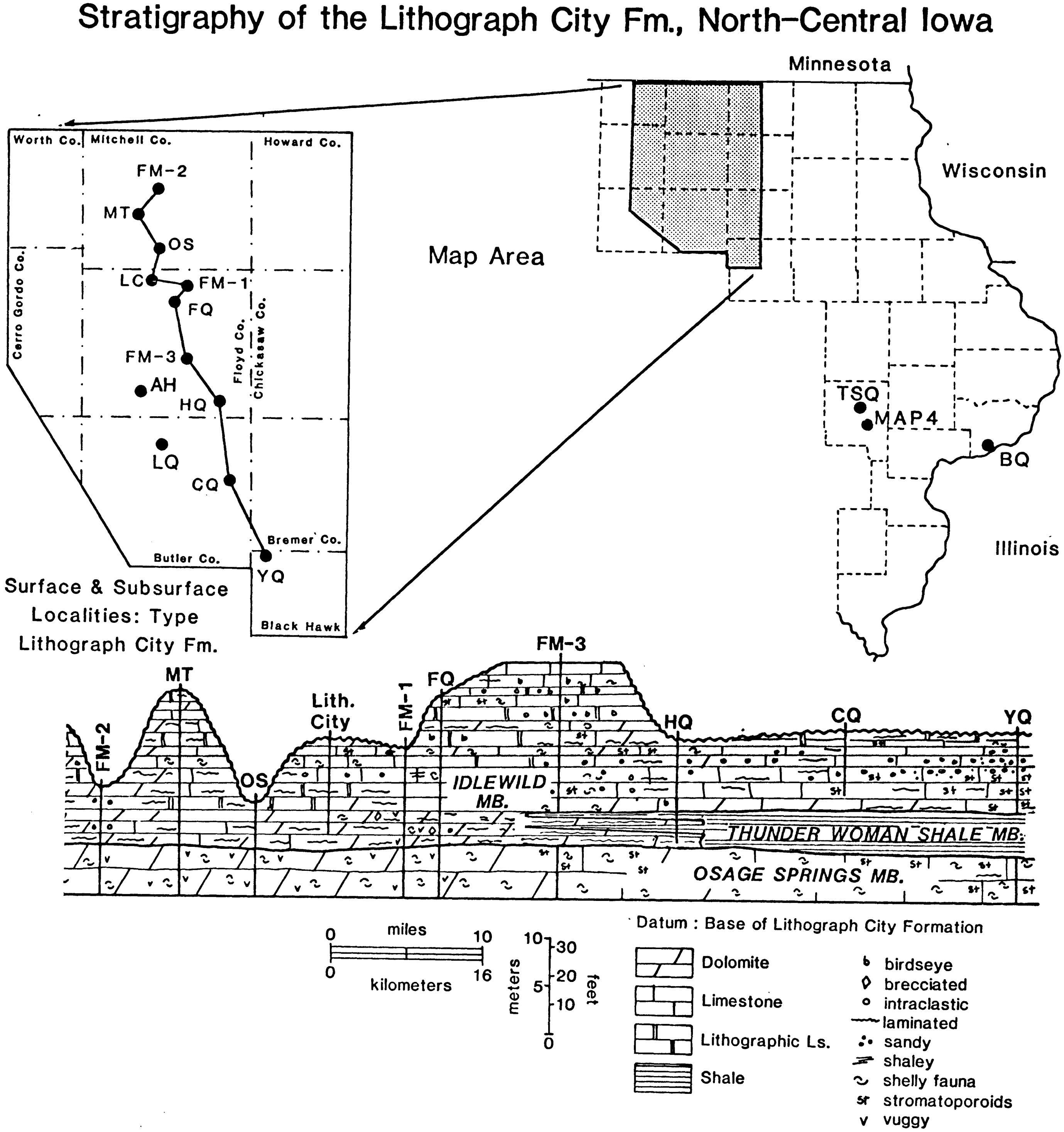


Figure 13. Generalized cross-section of the Lithograph City Formation of the Lithograph City in its type area in north-central Iowa. Modified from figs. 1 & 6 of Bunker et al., 1986, and fig. 5A of Day 1989a. Locality Key: FM-2=Floyd-Mitchell Project Hole #2, MT=Mitchell, Iowa, OS=Osage Springs, LC=Lithograph City, FM-1=Floyd-Mitchell Project Hole #1, FQ=Floyd Quarry, FM-3=Floyd-Mitchell Project Hole #3, HQ=Hanneman Quarry (see Fig. 14, Appendix), CQ=Clarksville Quarry, YQ=Yokum Quarry, AH=Aureola Hills-Maxson Quarry (stop 3 of Bunker et al., 1986).

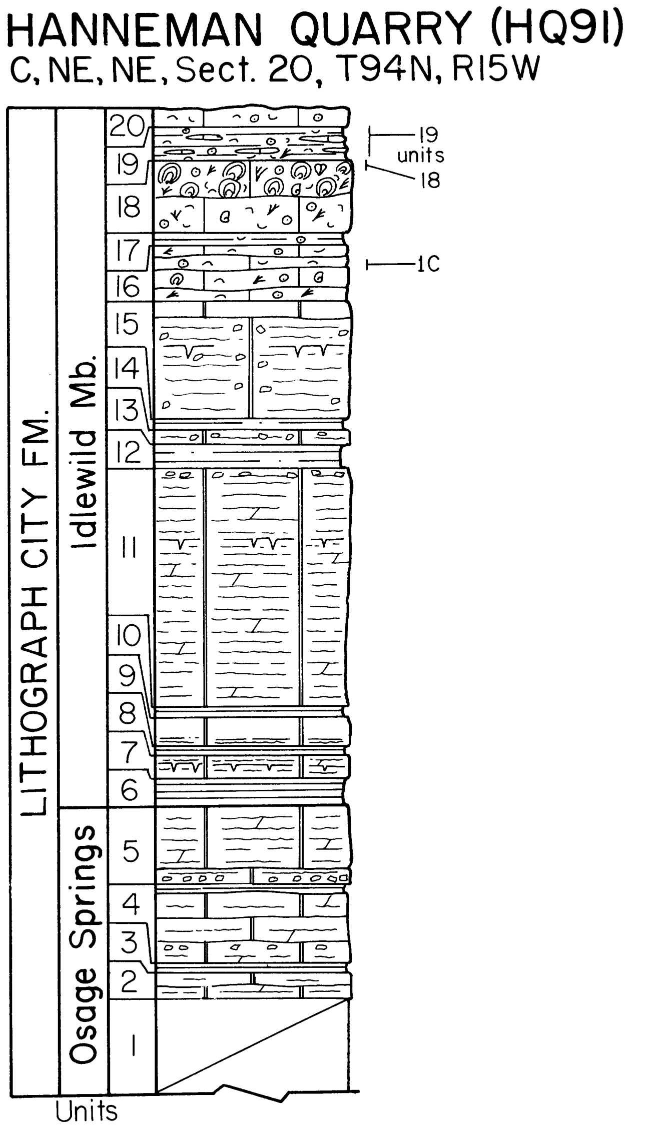


Figure 14. Measured section of the Lithograph City Formation at Hanneman Quarry (locality HQ in Fig. 13). Lithic and fossil symbols as in Figure 5. See Appendix for a detailed section description.

Strophodonta iowensis, Schizophoria lata, Cranaena n. sp., the bivalve *Paracyclus* sp. cf. *P. rowleyi*, branching and hemispherical stromatoporoids, conodonts (see Kralick, this guidebook), and gastropods.

Twenty-three of the twenty-nine species of brachiopods known from the Lithograph City Formation were described by Calvin (1876, 1897), Webster (1921), Branson (1922, 1940), Thomas and Stainbrook (1922), Fenton and Fenton (1924, 1935), Stainbrook and Ladd (1924), Belanski (1928a, 1928b), Stainbrook (1938b, 1943a, 1943b), Warren (1942, 1944), and Norris (1983). Day (1986, 1989a, 1989b) outlined the composition and stratigraphic significance of the Lithograph City brachiopod fauna and made close comparisons coeval with latest Givetian-early Frasnian faunas in Nevada, New York, and central and western Canada. Day (1989a) described six Lithograph City faunas based on brachiopod assemblages from its various members, and discussed occurrences of undescribed species of *Cranaena, Eleutherokomma, Floweria,* and *Strophodonta.*

Revisions to Lithograph City Brachiopod Identifications

Ongoing systematic study of the Lithograph City brachiopod fauna by the author neccessitates revisions to identifications of certain taxa identified and listed in earler works by Day (1986, 1989a, 1989b). *Pugnoides solon* Thomas and Stainbrook, was erroneously assigned to the genus *Ladogioides* McLaren by Day (1989a), and is reassigned to the genus *Hadrorhynchia* McLaren (Table 3). Revisions to State Quarry *Tecnocyrtina* are discussed at length in the next section of this report. Specimens of *Allanella* from the upper 4-5 meters of the Idlewild Member in northern Iowa (Tables 3-5), formerly grouped in *A. allani* by Day (1989a) are now considered to be a new species, descendent from *A. allani*, and ancestral to *A. cardinalis* that occurs in younger Frasnian strata of the Mason City Member of the Shell Rock Formation (Belanski, 1928a; Day, 1989a).

Atrypids from the Andalusia, State Quarry, and lower Osage Springs members listed as *Independatrypa independensis* by Day (1989a, 1989b) are conspecific with *I. scutiformis* (Stainbrook). *Atrypa rugatula* Stainbrook and Ladd was erroneously assigned to *Radiatrypa* (*Variatrypa*) by Day (1989a), and is most closely related to *Pseudoatrypa* because of its biconvexity, crowded growth lamellae, and closely-spaced frills. Atrypids identified from the Idlewild Member as *Variatrypa lineata* (Webster) by Day (1989a) are more closely allied to *Pseudoatrypa* because of the development of frills in older growth stages, and are listed here as *P.*? *lineata* (Tables 3-5).

New Brachiopod Species Occurrences

Pending formal systematic description, I have left all new brachiopod species from the Lithograph City

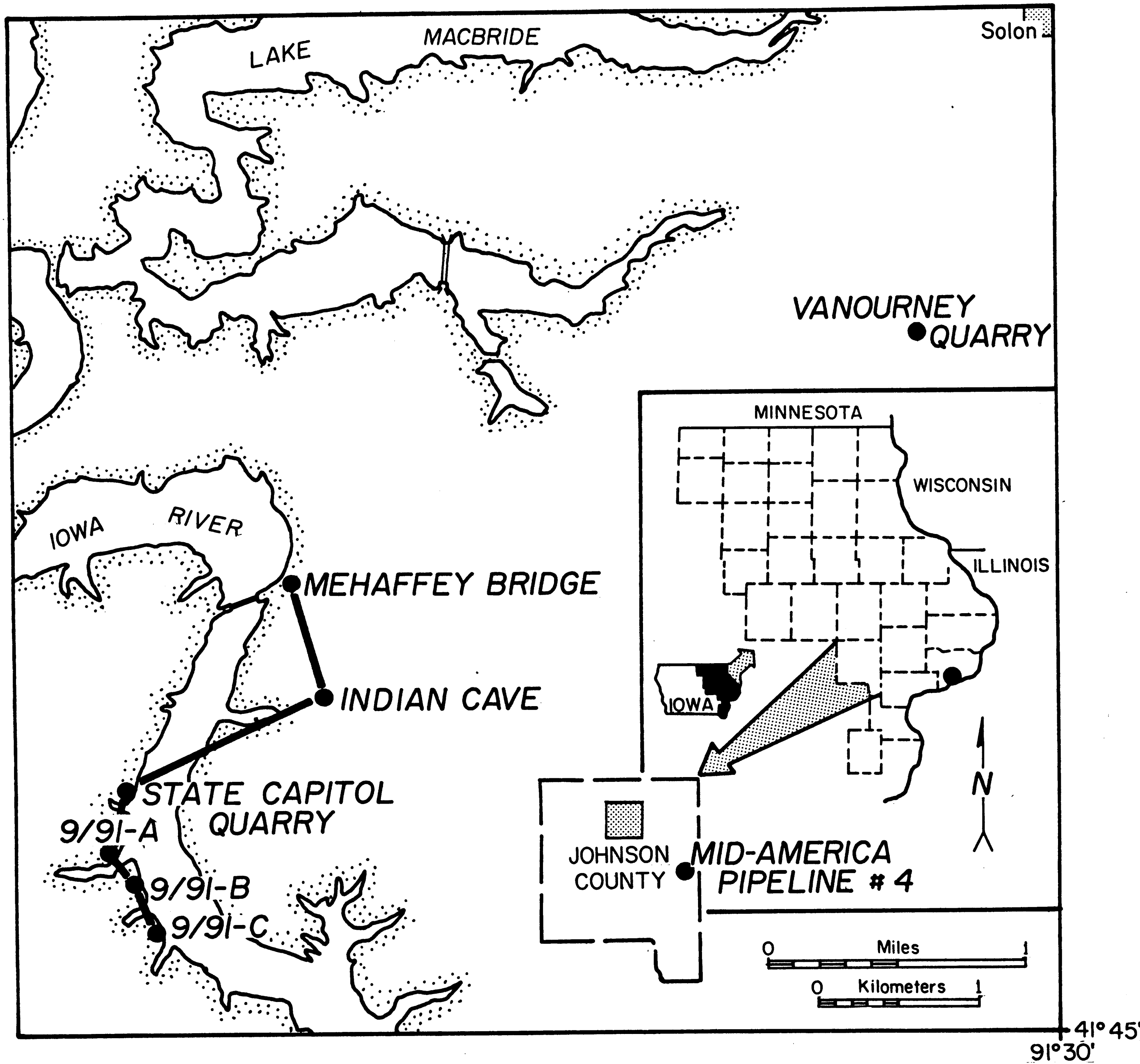
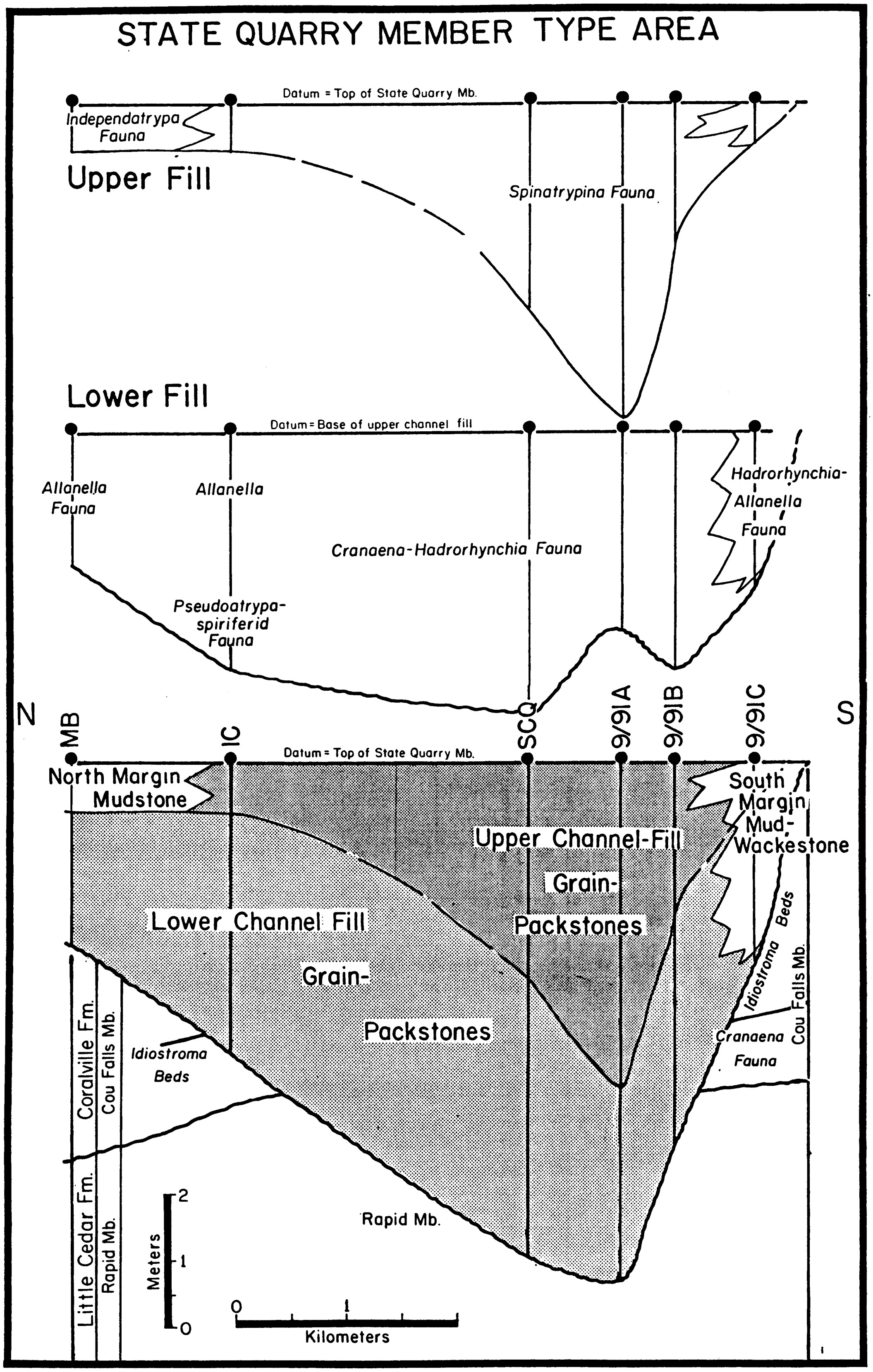


Figure 15. (above) Map of the Coralville Reservoir area, Johnson County, showing locations of outcrop, quarry exposures, and wells with important sections of the State Quarry Member of the Lithograph City Formation. Localities also shown in Figure 4.

Figure 16. (opposite page) Cross-section of the State Quarry Member in its type area along the east and west shores of Coralville Lake with locations of sections shown in Figure 15. The lowermost cross-section shows the "main" State Quarry Member channel-fill sequence indicating lithologic composition of the "Lower" and "Upper" fill sequences, and the north and south channel-margin mudbank facies. The middle cross-section shows the geometry of the "Lower" channel-fill complex and distribution of major brachiopod faunas (Fig. 15). The upper cross-section shows the geometry of the "Upper" channel-fill complex and distribution of important brachiopod faunas described herein (Fig. 15). The lower channel-fill complex corresponds to the "lower lentil" of the State Quarry Member as described by Watson (1974), and the upper channel-fill complex corresponds to the "middle and upper lentils" of Watson (1974).



STATE QUARRY MEMBER TYPE AREA
Datum = Top of State Quarry Mb.
Independatrypa Fauna
Upper Fill
Spinatrypina Fauna
Lower Fill
Datum = Base of upper channel fill
Allanella Fauna
Allanella
Cranaena-Hadrorhynchia Fauna
Hadrorhynchia-Allanella Fauna
Pseudoatrypa-spiriferid Fauna
N
S
MB
IC
SCQ
9/91A
9/91B
9/91C
Datum = Top of State Quarry Mb.
North Margin Mudstone
South Margin Mud-Wackestone
Upper Channel-Fill Grain-Packstones
Lower Channel Fill Grain-Packstones
Idiostroma Beds
Cranaena Fauna
Coralville Fm.
Cou Falls Mb.
Little Cedar Fm.
Rapid Mb.
Meters
2
1
0
Kilometers

BRACHIOPOD ASSEMBLAGES STATE QUARRY MB.

	Pseudoatrypa-spiriferid	*Cranaena-Hadrorhynchia*	*Allanella*	*Spinatrypina*	*Hadrorhynchia-Allanella*	*Independatrypa*
Allanella allani	●	●	●	●	●	
Athyris simplex	●	●	●	●	●	
Cranaena depressa	●	●	●			
Cyrtina sp. A	●	●		●		
Devonoproductus reticulocostus					●	
Eleutherokomma n. sp. A	●					
Eosyringothyris occidentalis			●			
Floweria altirostris		●		●		
Hadrorhynchia solon	●	●		●	●	
Independatrypa scutiformis					●	●
Orthospirifer capax	●					
Pseudoatrypa rugatula	●	●		●		
Schizophoria lata						●
Strophodonta iowensis		●		●	●	
Spinatrypina n. sp.		●		●		
Tecnocyrtina missouriensis n. ssp.	●					
Spathella sp.					●	

Figure 17. Composition of brachiopod assemblages from the State Quarry Member in Johnson County, eastern Iowa. The State Quarry fauna was formerly referred to as the *Ladogioides* Fauna by Day (1989a, 1989b), is divided into six faunas whose distribution is shown in Figure 16.

Formation in open nomenclature in Table 3. A number of new species occurrences have been documented from various members of the the Lithograph City, and represent the genera *Cranaena*, *Cyrtina*, *Devonoproductus*, *Eleutherokomma*, *Floweria*, *Productella*, *Spinatrypina* (*S.*), *Strophodonta*(*S.*), and *Tecnocyrtina.*

The brachiopod described as *Tecnocyrtina* sp. *A* by Norris (1981, p. 21, pl. 8, figs. 18-24) from the Waterways Formation of Alberta occurs in the Andalusia and State Quarry members of the Lithograph City in Iowa. Norris's (1981) species is not a true *Tecnocyrtina* owing to the lack of costae on the fold or sulcus, and consequently is listed as *Cyrtina* sp. A in Table 3 and Figures 11 and 17. This species was illustrated by Branson (1922, p. 108, pl. 19, figs. 9-12) under the name *Cyrtina triquetra* Hall from the Snyder Creek Formation of central Missouri.

The State Quarry species of *Tecnocyrtina* is considered by the author to be a new subspecies of *T. missouriensis* (Swallow, 1860). Stainbrook (1943b) illustrated *T. missouriensis* and stated that this species occurred in the Rapid Member of the Little Cedar Formation of Iowa. All *Tecnocyrtina* material illustrated by Stainbrook (ibid.) came from Missouri, and at this time no specimens of *T. missouriensis* are known to occur in the Little Cedar Formation in Iowa. In Iowa, the oldest *Tecnocyrtina* first occurs in the Gizzard Creek Member of the Coralville Formation. As currently understood, the range of *Tecnocyrtina* in the Devonian of the midcontinent begins in the interval of the Upper *subterminus* Fauna (approx. = upper part of the *disparilis* Zone) through the interval of the lower part of the *P. insita* Fauna (*norrisi* Zone), or *Tecnocyrtina missouriensis* Zone-*Allanella allani* Zone (Fig. 3).

Hadrorhynchia solon (Thomas and Stainbrook) was recovered from the upper half of the Andalusia Member in Scott County, Iowa (Table 3). *Hadrorhynchia solon* was illustrated by Fraunfelter (1974, p. 55, pl. 22, figs. 18-19) as *Stenocisma* sp. 2. from the upper part of the Callaway Formation, and ranges as high as the upper part of the Snyder Creek Shale of central Missouri (Branson, 1922 = *Pugnoides altus*, p. 92, pl. 16, figs. 10-12). The range of *Hadrorhynchia solon* corresponds to the interval of the *norrisi* Zone as it may be represented in the State Quarry Member (*Allanella allani* Zone) through strata with conodonts correlated with Montagne Noire Zone 3 (Klapper, 1989) in Missouri (Schumacher, 1976; Johnson and Klapper, 1992).

Cranaena n. sp., a transverse and dorso-ventrally compressed species, (Table 3) was recently recovered from the uppermost Lithograph City Formation at the Garrison Quarry (unit 27, STOP 1) in association with *Allanella allani.* Previously, *C.* n. sp. was only known from the upper Andalusia Member of eastern Iowa (Day, 1989a, 1989b). *Cranaena infrequens* was originally described by Belanski (1928b) from "Cedar Valley" strata in north-central Iowa, and occurs in the upper part of the Osage Springs and Idlewild members (Figs. 2, 3, 13).

Two large undescribed species of *Eleutherokomma* (*E.* n. sp. A) and *E.* n. sp. B (= *E. jasperensis* of Day 1989a)) occur in the State Quarry and Idlewild members, respectively. The latter species (*E.* sp. B) ranges into the Mason City Member of the Shell Rock Formation. *Eleutherokomma* n. sp. A is a rare element of the *Cranaena-Hadrorhychia* Fauna of the lower State Quarry Member in Johnson County (Figs. 12-14). *Orthospirifer capax* (Hall), previously known only from the Andalusia Member, is reported here from the State Quarry Member at the Indian Cave section in Johnson County (Figs. 15-18).

The oldest *Devonoproductus* known from the

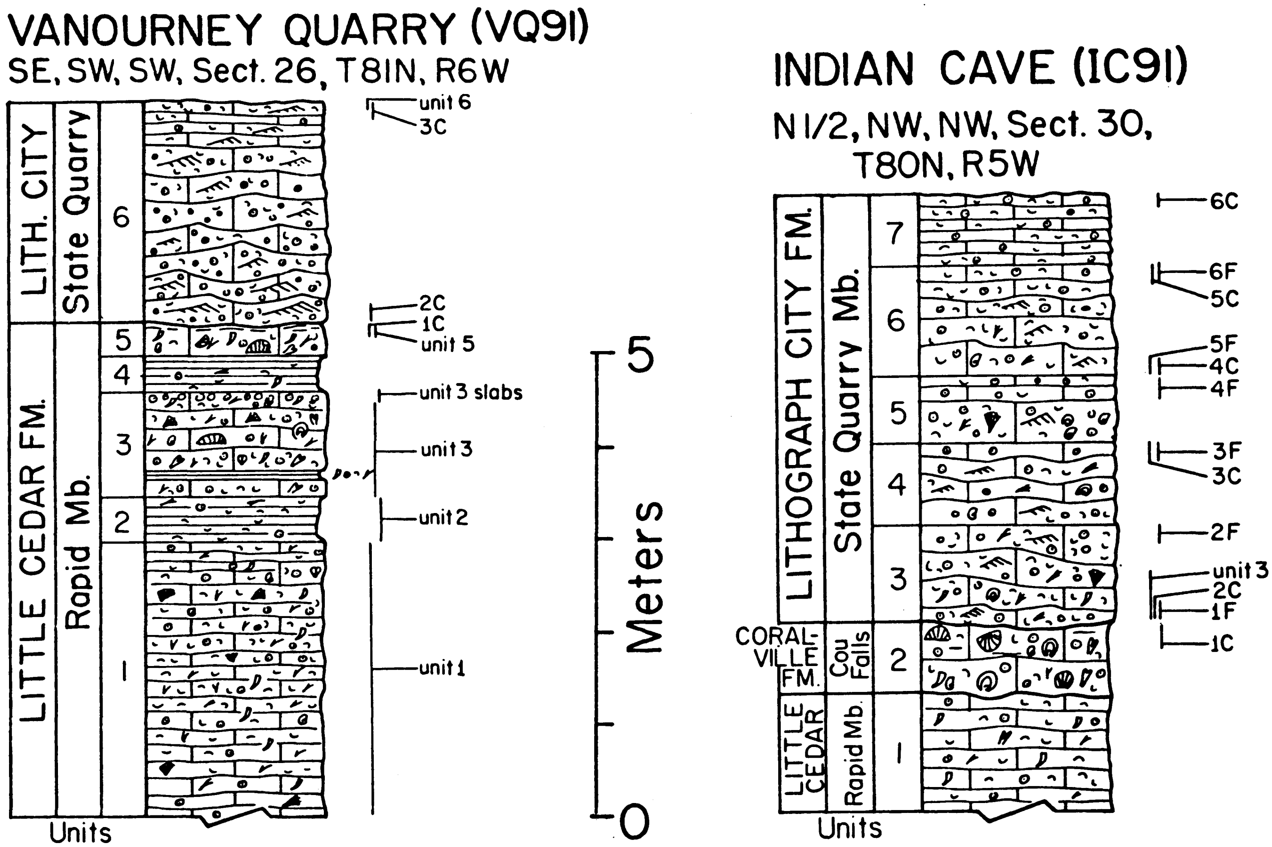


Figure 18. Measured sections of Devonian strata at Indian Cave and the Vanourney Quarry (localities IC & VQ, Figs. 4 & 15), Johnson County, Iowa. Lithic and fossil symbols as in Figure 5. Section descriptions given in the Appendix of this report.

Givetian-Frasnian brachiopod sequence of Iowa was recovered by B. Witzke (Iowa DNR Geological Survey Bureau) from skeletal mudstones of the State Quarry Member on the west shore of Coralville Reservoir (Figs. 12-14, locality 9/91-C). In Iowa, *Devonoproductus walcotti* and *D. vulgaris* occur in late Frasnian strata of the Lime Creek Formation (Fenton and Fenton, 1924; Day, 1989a) or the Independence Shale (Stainbrook, 1945; Day, 1989a), respectively. The State Quarry *Devonoproductus* is assigned to *D. reticulocostus* Norris, originally described from the Waterways Formation of northeastern Alberta (Norris, 1983). This species also occurs in the Snyder Creek Shale of central Missouri (collections of the author). A single specimen of *Productella* sp. occurs in Belanski's collections (Table 5) from the uppermost Idlewild Member, and is most similar to *P. fragilis* Belanski from the Mason City Member of the Shell Rock Formation.

Forms grouped in *Strophodonta* (*S.*) n. sp. A (=*S.* (*S.*) *callawayensis* of this report) and reported from the upper Idlewild Member from northern Iowa by Day (1989a), are now considered to be conspecific with *S.* (*S.*) *scottensis* (Belanski) as listed in Table 3. This species was first described by Belanski (1928a) from younger Frasnian strata of the Mason City Member of the Shell Rock Formation, and its occurrence in the Idlewild allows for extension of the range of this species in the Iowa Devonian brachiopod sequence.

A single specimen clearly assignable to

Table 4. Composition of brachiopod assemblages assigned to the *Allanella* Fauna from sampled measured sections of the Lithograph City Formation of north-central Iowa in the Belanski Register and Collection (Univ. Iowa (SUI) Paleontology Repository). Detailed locations of all Belanski fossil localities are described in the Belanski Register, or in Strimple and Leverson (1969). Species described as present in units (Belanski Register) but not represented specimens in the Belanski Collection are designated by +.

Species	Belanski Locality						
	49-5	49-6	49-7	60-4	60-5	60-6	60-7
Allanella allani	+	3	3	6	+	-	-
A. n. sp.	-	-	-	-	-	-	-
Athyris vittata	+	3	5	-	+	-	+
Floweria n. sp.	+	1	-	-	-	-	-
Pseudoatrypa? *lineata*	+	11	8	-	-	+	-
Strophodonta (*S.*) *scottensis*	+	14	1	-	-	-	-

Table 4 continued.

Species	Belanski Locality					
	123-	123-15	123-17	129-2	129-5	129-7
Allanella allani	19	-	15	4	+	+
A. n. sp.	-	-	-	-	-	-
Athyris vittata	9	125	24	-	+	+
Floweria n. sp.	1	1	1	-	-	-
Pseudoatrypa? *lineata*	5	29	2	-	-	-
Strophodonta (*S.*) *scottensis*	33	3	1	1	-	-

Table 5. Composition of brachiopod assemblages assigned to the *Eleutherokomma* Fauna from measured sections of the upper part of the Idlewild Member of the Lithograph City Formation of northern Iowa. All fossil samples are from the Belanski Collection (SUI Paleontology Repository). Detailed locations of Belanski sample localities are given in the Belanski Register, or in Strimple & Leverson (1969). * = present in sampled unit according to section description (Belanski Register), not present in collections (Belanski Collections).

Species	Belanski Locality					
	10-1	10-2	10-4	56-1	56-3	56-4
Allanella n. sp.	4	-	-	1	-	-
Athyris vittata	1	-	-	-	-	-
Eleutherokomma n. sp. B	14	8	5	5	*	*
Floweria n. sp.	-	*	-	-	-	-
Pseudoatrypa? *l*	2	-	-	3	-	-
Productella cf. *fragilis*	-	*	-	-	-	-
Strophodonta (*S.*) *scottensis*	-	*	-	-	-	-
Cranaena infrequens	-	-	-	-	-	-

Strophodonta (*S.*) *inflexa* (Swallow) was recently recovered from the upper Idlewild Member at Hanneman Quarry (Fig. 13) in the fauna of unit 19 (Fig. 14) with *S.* (*S.*) *scottensis*, *Pseudoatrypa*? *lineata*, and *Allanella* n. sp. This occurrence is significant because it was first named (Swallow, 1860) and illustrated (Branson, 1922; 1944) from the fauna of the Sydner Creek Shale of central Missouri. This same species occurs in, and was illustrated from, strata of the Calumet Member of the Waterways Formation of northeastrn Alberta (Norris, 1983, pl. 6, figs. 2-14) at a position above conodont faunas correlated with the Lower *asymmetricus* Zone (=lower Frasnian).

Brachiopod Faunas of the Lithograph City Formation

A variety of brachiopod biofacies can be recognized in the diverse suites of lithofacies that compose the Lithograph City Formation in north-c contain Pseudoatrypa? lineata, Allanella allani, and Athyris vittata. The stromatoporoid biostrome biofacies of *the upper* 1.5 met*ers of the O*sage *Springs Member* at Yokum Quarry in northwestern Blackhawk C*ounty (Fig.* 13; Day, in Bunker et al., 1986; Day, 1989a; Witzk*e et al., 1989, fig. 11G) cont*ains abundant Pseudoatrypa? lineata, with smaller numbers of AllanelIn the type area of the Lithograph City Formation, fossil assemblages of the *Allanella* Fauna (Day, 1989a) occur in the Osage Springs and in the lower and middle parts of the Idlewild Member. Assemblages assigned to the Upper *Strophodonta* Fauna occur in biostromal facies in the lower part of the upper Idlewild. Assemblages of the *Eleuthrokomma* Fauna overlie the aforementioned faunas, and characterize strata of the upper Idlewild Member.

Osage Springs Member

Elements of the brachiopod fauna of the Osage Springs Member (Fig. 13; Table 3) were first described by Webster (1921), Belanski (1928b), and Fenton and Fenton (1935). Webster (1921) and Fenton and Fenton (1935) described *Atrypa lineata* (=*Pseudoatrypa*?, Table 3). Belanski (1928a) described the terebratulid *Cranaena infrequens* and collected specimens of this species from strata of both the Osage Springs and Idlewild members. Day (1986, 1989a) outlined the composition of brachiopod fauna of the Osage Springs and discussed its biostratigraphic significance.

***Allanella* Fauna (revised).** Fossil assemblages in the Osage Springs Member in north-central Iowa included in the *Allanella* Fauna are either low-diversity assemblages containing *Allanella allani* and *Athryis vittata*, found in skeletal mudstones or wackestones, or moderate-high diversity (3-10 species) brachiopod assemblages associated with echinoderms and stromatoporoids (biostromal biofacies). Assemblages associated with stromatoporoid biostromal intervals occur at the Charles City South Quarry (Day, in Bunker et al., 1986) and contain *Pseudoatrypa*? *lineata*, *Allanella allani*, and *Athyris vittata*. The stromatoporoid biostrome biofacies of the upper 1.5 meters of the Osage Springs Member at Yokum Quarry in northwestern Blackhawk County (Fig. 13; Day, in Bunker et al., 1986; Day, 1989a; Witzke et al., 1989, fig. 11G) contains abundant *Pseudoatrypa*? *lineata*, with smaller numbers of *Allanella allani*, *Strophodonta* (*S.*) *iowensis*, *Athyris vittata*, *Floweria altirostris*, and *Cranaena infrequens*. Idlewild Member brachiopod assemblages associated with stromatoporoid biostromal facies are very similar to those of the older Osage Springs Member.

Idlewild Member

Elements of the brachiopod fauna of the Idlewild Member were first described by Belanski (1928a, *Strophodonta* (*S.*) *scottensis*; 1928b *Cranaena infrequens* = *C.* sp. cf. *iowensis* in Day, 1989a, p. 308), Webster (1921, *Pseudoatrypa*? *lineata*), and Stainbrook (1940a, *Schizophoria lata*). Day (1989a) described the Upper *Strophodonta* and *Eleutherokomma* faunas from the Idlewild Member. Skeletal mudstones and wackestones in the lower two thirds of the Idlewild Member (Fig. 13) contain brachiopod assemblages identical to those of the low-diversity assemblages of the *Allanella* Fauna of the Osage Springs Member. *Allanella*-dominated assemblages of the upper Idlewild Member differ from those of the Osage Springs and lower and middle Idlewild in that *A. allani* is replaced by its descendent *A.* n. sp.

Upper *Strophodonta* Fauna (revised). At Hanneman Quarry (Fig. 13, locality HQ; Fig. 14) skeletal limestones with locally developed branching stromatoporoid thicket and hemispherical stromatoporoid biostromes occur in the upper Idlewild Member (Fig. 14, units 18-20). These biostromal units contain assemblages of the Upper *Strophodonta* Fauna. This fauna is dominanted by large numbers of *Athyris vittata*, *Pseudoatrypa*? *lineata*, *Allanella*n. sp., with smaller numbers of *Floweria* n. sp. aff. *F. altirostris*, *Strophodonta (S.) inflexa, S.(S). scottensis, Cranaena infrequens, Schizophoria lata,* and *Gypidulina* n. sp.

A number of sections featuring biostromal facies of the lower part of the upper Idlewild were described and sampled by Charles Belanski in the first quarter of this century. Belanski's lower and middle Idlewild collections (Table 4) from southern Floyd County contain *Strophodonta scottensis, Allanella* n. sp., *Athyris vittata,* Pseudoatrypa*?* lineata*, and* Floweria *n. sp.*

***Eleutherokomma* Fauna.** This fauna includes brachiopod assemblages (Belanski Collection, SUI Repository) from skeletal mudstones and wackestones in the upper 1-3 meters of the Idlewild (where preserved) west of the town of Marble Rock in south-central Floyd County (near locality AH, Fig. 13; stop 4, Bunker et al., 1986), and south of the town of Nora Springs along the Shell Rock River in Cerro Gordo County (Table 5). This fauna has common very large specimens of *Eleutherokomma* n. sp. B (=*E.* sp. cf. *E. jasperensis* of Day, 1989a), with some or all of the following species: *Allanella* n. sp., *Pseudoatrypa*? *lineata, Strophodonta scottensis, Floweria* n. sp., and *Athyris vittata.*

State Quarry Member

Brachiopods occur in all lithologies of the State Quarry Member where it is known to crop out in Johnson County (Watson, 1974; Day, 1986, 1989a, 1989b). A number of different brachiopod assemblages were noted in the State Quarry Member by Watson, (1974), and were described collectively as the *Ladogioides* Fauna by Day (1989a, 1989b).

The State Quarry Member and elements of its fauna were first described by Calvin (1897). Thomas and Stainbrook (1922) described the rhynchonellid *Pugnoides solon* from the State Quarry beds in the Johnson County area. Fenton and Fenton (1924) illustrated a specimen of *P. solon* (p. 129, pl. 25, figs. 9-12) from the State Quarry in their monograph on the Lime Creek fauna. Stainbrook and Ladd (1924) described over half of the brachiopod species known from this unit. Stainbrook (1938b) originally described *Atrypa scutiformis* (now *Independatrypa scutiformis* (Stainbrook, 1938)) and *Stropheodonta iowensis* (now *Strophodonta* (*S.*) *iowensis* (Stainbrook, 1938)) from strata now assigned to the Andalusia Member of the Lithograph City Formation. Stainbrook (1940b) described *Schizophoria lata* from strata now assigned to the Andalusia Member in Scott County. This species is now known from all members (except the Thunder Woman Shale) of the Lithograph City Formation, as well as other latest Givetian and early Frasnian deposits in western Canada (Norris, 1983).

Watson (1974) documented brachiopod occurrences in numerous State Quarry sections in the Johnson County area. Day (1986, 1989a, 1989b) discussed the composition and biostratigraphic significance of the State Quarry brachiopod fauna. Day (1989a, table 2) listed *Schizophoria* sp. aff. *S. athabaskensis* from the State Quarry Member. This species occurs in the Waterways Formation of northeastern Alberta (Warren, 1944; Norris 1983), and is not known with certainty from the Lithograph City Formation of Iowa. This species does occur in the Snyder Creek Shale in central Missouri (=*S. striatula* (Scholtheim) in Branson, 1922, p. 72, pl. 17, figs. 1-7; Branson, 1944, p. 148, pl. 23, figs. 20, 21).

Recent studies of the State Quarry Member in its type area (Fig. 12) allow for description of six distinctive brachiopod associations from the State Quarry (Figs. 13, 14). Quantitative analyses of State Quarry brachiopod faunas is not attempted in this study. State Quarry brachiopod faunas descussed herein are as follows: *Pseudoatrypa*-spiriferid, *Allanella, Cranaena-Hadrorhynchia, Hadrorhynchia-Allanella, Independatrypa,* and *Spinatrypina* faunas (Fig. 13).

***Pseudoatrypa*-spiriferid Fauna (new).** Brachiopod assemblages grouped in the *Pseudoatrypa*-spiriferid Fauna occur in the lower channel-fill skeletal grainstone and packstone sequence (Figs. 12, 13; =lower lentil of the State Quarry of Watson, 1974) of the State Quarry Member on the eastern side of Coralville Reservoir. Fossil assemblages from lower part of the State Quarry Member at the Indian Cave locality (Fig. 18) contain abundant *Pseudoatrypa rugatula,* with *Allanella allani, Cyrtina* sp. A, *Tecnocyrtina missouriensis* n. ssp., *Cranaena depressa, Athyris simplex,* and rare *Hadrorhynchia solon, Orthospirifer capax,* and *Spinatrypina* n. sp. Brachiopods of this fauna occur in association with small domal and branching stromatoporoids, solitary tetracorals (*Tabulophyllum* sp.), large gastropods, fish fragments, fenestellid bryozoans, and echinoderms.

***Allanella* Fauna (new).** The *Allanella* Fauna of the State Quarry Member (Figs. 16, 17) includes assemblages containing abundant *Allanella allani,* in association with *Athyris simplex, Pseudoatrypa rugatula, Cyrtina* sp. A, and rare *Spinatrypina* n. sp. in skeletal grainstone and packstones of the lower part of the State Quarry Member at the Mehaffey Bridge section (Figs. 15-17; Bunker and Witzke, 1987) and the upper 1.5-2.0

meters of the State Quarry at the Indian Cave section (Figs. 15-17, units 6 and 7, Appendix). Brachiopod assemblages in the upper 0.5 meters of the State Quarry at Vanourney Quarry (Figs. 15, 18, Appendix), composed almost entirely of *A. allani* with small numbers of *Eosyringothyris occidentalis*, are included here in the *Allanella* Fauna.

***Hadrorhynchia-Allanella* Fauna (new).** The *Hadrorhynchia-Allanella* Fauna (Figs. 16, 17) includes the fossil assemblages from the thin (5-15 cm) basal skeletal packstones and overlying skeletal wackestones and mudstones at section locality 9/91-C (Figs. 15, 16) of the State Quarry Member in Johnson County. Included in this fauna are: assemblages with abundant *Hadrorhynchia solon*, *Athyris simplex*, *Allanella allani*, and *Cyrtina* sp. in the skeletal packstones of the lower 10-20 cm of the State Quarry as locality 9/91-C (Figs. 15, 16); and assemblages in the overlying 2.4 meters of skeletal mudstones and wackestone, with scattered shell lags. These units at locality 9/91-C contain the aforementioned taxa with scattered *Cranaena depressa*, *Devonoproductus reticulocostus*, *Strophodonta iowensis*, and rare *Independatrypa scutiformis*. Gastropods and bivalves (*Spathella* sp. cf. *S.*) also occur in the mudstones of the southern State Quarry channel margin facies (Fig. 16).

***Cranaena-Hadrorhynchia* Fauna (new).** This fauna (Figs. 16, 17) includes brachiopod assemblages from the lower skeletal grainstones and packstones of the lower 3-4 meters of the State Quarry Member on the western shore of the Coralville Reservoir at localities SCQ, 9/91-A, and 9/91-B (Figs. 15-17). The major skeletal components of these units are echinoderms, and whole shell and abraded brachiopods. *Cranaena depressa*, *Hadrorhynchia solon*, *Pseudoatrypa rugatula*, and *Athyris simplex* are abundant, with *Floweria altirostris* and/or *Allanella allani* locally very abundant (especially at locality 9/91-A, Figs. 15-16). Small numbers of *Spinatrypina* n. sp. and *Eleutherokomma* n. sp. A occur in this fauna (Fig. 17).

***Independatrypa* Fauna (new).** The *Independatrypa* Fauna is defined here on the brachiopod assemblages that occur in skeletal mudstones and wackestones that make up the upper meter of the Mehaffey Bridge section of the State Quarry Member (Figs. 15-17). These strata are shown in Figure 16 as the "north channel margin mudstones and wackestones" and contain very abundant *Independatrypa scutiformis*, and very rare *Schizophoria lata*, and *Athyris vitatta* (Fig. 17).

***Spinatrypina* Fauna (new).** *Spinatrypina* n. sp. is most abundant in the upper channel fill succession of State Quarry Member as seen in exposures on the western shore of Coralville Lake (Figs. 15-17). Whole brachiopod valves are less common and abundant in strata of the upper fill complex (Fig. 16), but do include *S.* n. sp., *Hadrorhynchia solon*, *Cyrtina* sp. A, *Athyris simplex*, *Allanella allani*, *Strophodonta* (*S.*) *iowensis*, and *Floweria altirostris*. This fauna is best developed in the upper 3-4 meters of the State Quarry exposed in the valley walls at locality 9/91-B (Figs. 15, 16).

Andalusia Member

The brachiopod fauna of the Andalusia Member (Table 3) is dominated by species of *Strophodonta* (*S.*), *Schizophoria*, and *Independatrypa* (Day, 1989a). This unit is best exposed at the Davenport Cement Company Quarry near the town of Buffalo (Fig. 15) in Scott County, Iowa (Witzke et al., 1985; 1989; Bunker et al., 1986). Additional exposures of the Andalusia Member can be seen to the west in stream drainges near the town of Montpelier, and along Pine Creek in Muscatine County, Iowa.

Hall (1858) and Stainbrook (1938b, 1940b, 1942, 1943a, 1943b) described most of the fauna known from the Andalusia Member at exposures near Buffalo along the Mississippi River. Stainbrook (1938b, 1943a) described atrypoid, strophodontid, and spiriferid (1943b) brachiopods from strata designated as the "*Stropheodonta iowensis* zonule" of the "*waterlooensis* Zone".

lower *Strophodonta* Fauna. Day (1989a) assigned the brachiopod fauna from the lower part of the Andalusia Member to the lower *Strophodonta* Fauna. At the Davenport Cement Co. Quarry in Scott County (Fig. 10) the "lower" Andalusia Member (Figs. 10, 11; samples 9-14 of Fig. 11) contains a brachiopod fauna consisting of extremely abundant *Strophodonta* (*S.*) *iowensis*, with smaller numbers of *Independatrypa scutiformis*, and *Schizophoria lata*.

Athyris vittata, *Tecnocyrtina missouriensis*, *Allanella annae*, *Eosyringothyris occidentalis*, *Floweria sp.*, and the solitary tetracoral *Tabulophyllum callawayense* also weather from these shales and argillaceous skeletal packstones. Hall (1858) and Stainbrook (1938, 1940a, 1943a) described most of the "lower" Andalusia species from the basal shale (unit 8 of Fig. 10) of the Andalusia Member.

The *Orthospirifer* Fauna (revised). Strata of the "upper" Andalusia Member (Figs. 10, 11) consists of thick-bedded and massive dolomites interbedded with shaley biostromal units in the lower part (Fig. 10, units 11-15b) and contain low and moderate diversity brachiopod assemblages (Table 3). James Hall (1858) and Stainbrook (1943a) collected *Orthospirifer capax* from units of the upper Andalusia. The *Orthospirifer* Fauna of the Andalusia was first described by Day (1989a) and is here divided into distinct lower and upper parts.

The lower part of the *Orthospirifer* Fauna is characterized by the assemblages from the "biostromal" wackestones and packstones of units 11-15b of Figure 10 (samples 16-22 in Fig. 11). The most abundant brachiopod in this interval is *Strophodonta (S.) callawayensis*, with smaller numbers of *Orthospirifer capax*, *Independatrypa scutiformis*, large *Schizophoria lata*, *Cyrtina* sp. A., *Athyris vittata*, *Allanella allani*, *Cranaena* n. sp., rare *Hadrorhynchia solon*, locally abundant and diverse orthoconic and cyrticonic nautiliod cephalopods, and large infaunal *Paracyclus rowleyi* (unit 11 of Fig. 10). Solitary tetracorals abundant in this interval are *Tabulophyllum callawayense* (A. Pedder, pers. comm.). Small well-preserved archaeogastropods also occur in this interval (Fig. 11) and are assigned to *Elasmonema*. The upper part of the *Orthospirifer* Fauna is characterized by the occurrence of locally abundant or common moldic *S. callawayensis* at the Buffalo Quarry (Figs. 10, 11, samples 24-27).

BRACHIOPOD ZONATION OF THE CEDAR VALLEY GROUP CENTRAL AND EASTERN IOWA

The first formal brachiopod-based assemblage zones for Cedar Valley Group strata (Fig. 3) were defined by Day (1989a). Subsequent stratigraphic and paleontologic investigations of Cedar Valley Group strata and faunas provide the basis for definition of three new zones based on the brachiopod and conodont sequences in the Little Cedar Formation (Figs. 3, 6), and revisions to the *Strophodonta plicata*, *S. (S.) iowensis*, and the *S. (S.)* n. sp. A Zones of Day (1989a).

The *Independatrypa independensis*, *Rhyssochonetes bellarugosis* (Lower and Upper Subzones), and the *Neatrypa waterlooensis* Zones are defined on the basis of the brachiopod sequence in the Little Cedar Formation (Figs. 3, 5, 6). The *Tecnocyrtina missouriensis missouriensis* Zone (Fig. 3) corresponds to, and replaces the *Strophodonta plicata* Zone of Day (1989a). The *Allanella allani* Zone (Fig. 3) is defined here to supplant the former *Strophodonta (S.) iowensis* Zone of the lower Lithograph City Formation (Day, 1989a). The *Strophodonta (S.)* n. sp. A. from the upper Andalusia Member of the Lithograph City Formation (Day, 1989a, 1989b) is considered to be conspecific with *S. (S.) callawayensis*, named by Swallow (1860) and illustrated in Branson (1944) from the upper Snyder Creek Shale of Missouri. Consequently, the *S. (S)*. n. sp. A Zone (Day, 1989a) is renamed the *S. (S.) callawayensis* Zone (Fig. 3).

Independatrypa independensis Zone (new)

The base of this zone is defined by the first occurrence of the atrypid *Independatrypa independensis* in the lower meter of the Solon Member in the Johnson County area of eastern Iowa (Figs. 3, 5, 6; STOP 4, fig. 1). This zone is also characterized by the range iniceptions of *Hypothyridina intermedia*, *Orthospirifer iowensis*, *Spinatrypa (S.) mascula*, *Pseudoatrypa bremerensis*, and *Seratrypa rustica* in the lower Solon Member (Figs. 3, 5, 6). As mentioned previously, and shown in Figure 3, brachiopod assemblages of the lower Solon occur in association with conodonts of the upper part of the Middle *varcus* Subzone (Witzke et al., 1989; Johnson and Klapper, 1992, fig. 1; Bunker and Witzke, this guidebook).

Rhyssochonetes bellarugosis Zone (new)

The base of this zone is defined on the first occurrence of *Rhyssochonetes bellarugosis* (Stainbrook) in the upper half of the Solon Member in Johnson County of eastern Iowa (Figs. 5, 6), and is characterized by range inceptions of *Striatochonetes schucherti*, *Atribonium swallovi*, *Charionella nortoni*, *Meristella parva*, and *Echinocoelia halli* with *R. bellarugosis* in the upper Solon interval (Fig. 6). This zone is divided into Lower and Upper subzones (Fig. 6). The base of the *R. bellarogosis* Zone is the base of the Lower subzone. In Iowa, the range of *Rhyssochonetes bellarugosis* is restricted to the upper Solon Member (Lower *R. bellarugsosis* Zone).

The base of the Upper *R. bellarugosis* Zone is defined on the first appearance of the productellid *Dichacaenia harberti*, and is characterized by range inceptions of *Spinatrypa (S.) bellula*, *Rhipidomella cuneata*, and *Seratrypa brandonensis* in the lower 4 meters of the Rapid Member in the Johnson County area (Figs. 5, 6). In eastern Iowa, the base of this subzone coincides with the base of the Rapid Member, and its brachiopod fauna (Fig. 6) occurs in association with the lowest conodonts (in Iowa) of the *hermanni* Zone.

Neatrypa waterlooensis Zone (new)

The base of this zone is defined at the position of the first occurrence of *Neatrypa waterlooensis* (WEBSTER, 1921) in the middle part of the Rapid Member in eastern Iowa (Figs. 5, 6). The lower boundary of this zone is characterized by the first occurrences of *Orthospirifer euruteines*, *Strophodonta* (*S.*) *parva*, *Pseudoatrypa blackhawkensis*, and *Cupularostrum cedarensis*. Brachiopod assemblages of the lower *Neatrypa waterlooensis* Zone are associated with conodonts of the *hermanni* Zone (undifferentiated), whereas brachiopod assemblages of the upper part of the *N. waterlooensis* Zone occur in association with conodonts of the Lower *subterminus* Fauna (Figs. 3, 6).

Tecnocyrtina missouriensis Zone (revised)

The base of this zone is defined by the first appearance of *Tecnocyrtina missouriensis missouriensis* in the *Tecnocyrtina* Fauna of the Gizzard Creek Member of the Coralville Formation in unit 12 of the Glory Quarry Section (Fig. 7, sample 7C). *Seratrypa rotunda* and *Independatrypa randalia* make their first appearances and serve to characterize the lower part of this zone. At the Mid-River Marina Quarry in Johnson County, the lower boundary of this zone is marked by first appearances of *Seratrypa rotunda* and *Independatypa randalia*, and is characterized by the first occurrences of *Strophodonta plicata*, *Strophodonta randalia*, *Cranaena iowensis*, and *Atribonium subovata*. In extreme eastern Iowa, the base of this zone corresponds to lower contact of the Cou Falls Member and includes the strata of the lower Cou Falls containing brachiopods of the *Strophodonta* Fauna and conodonts of the Upper *subterminus* Fauna (Figs. 10-12).

Conodonts of the Upper *subterminus* Fauna occur with brachiopods of the *Cranaena* and *Strophodonta* faunas in Johnson and Scott counties, respectively, and the *Tecnocyrtina* Fauna of the Gizzard Creek Member in Blackhawk County of central Iowa.

Allanella allani Zone (revised)

The base of this zone is defined by the first occurrence of *Allanella allani* in the lowermost part of the State Quarry Member in unit 1 at the Indian Cave locality (Figs. 15-17, unit 1 Fig. 17) on the east side of Coralville Lake, Johnson County, Iowa. The base of this zone is also characterized by first occurrences of *Cyrtina* sp. A, *Pseudoatrypa rugatula*, *Cranaena depressa*, *Hadrorhynchia solon*, and *Floweria altirostris*. Other species with first occurrences in this zone are *Allanella annae*, *Strophodonta* (*S.*) *iowensis*, *Eosyringothyris occidentalis*, *Schizophoria lata*, and *Independatrypa scutiformis*, as seen in the Andalusia Member in Scott County, Iowa (Figs. 10, 11).

State Quarry Member brachiopods of the *Allanella allani* Zone are associated with conodonts of the *insita* Fauna (*Skeletognathus norrisi* and *Pandorinellina insita*, Watson, 1974; Witzke et al., 1989; Klapper, in Johnson, 1990; Johnson and Klapper, 1992). In extreme eastern Iowa, the base of this zone is recognized by the first occurrences of *Allanella annae* with *Strophodonta iowensis* and the conodont *P. insita* in unit 8 of Figures 10-12 in the lowermost Andalusia Member of the Lithograph City Formation. In the type area of the Lithograph City Formation in north-central Iowa, *A. allani* occurs in the lower part of the Osage Springs Member with *P. insita* (Day, 1989a).

Strophodonta (*S.*) *callawayensis* Zone (revised)

The base of this zone corresponds exactly to that of the *Strophodonta* (*S.*) n. sp. A Zone of Day (1989a). The base of this zone is defined by the first occurrence of *Strophodonta* (*S.*) *callwayensis* in the fauna of unit 11 of the Andalusia Member (Figs. 10, 11) of the Lithograph City Formation at the Buffalo Quarry in Scott County, Iowa. *Allanella allani*, *Cyrtina* sp. A, *Orthospirifer capax*, *Independatrypa scutiformis*, *Hadrorhynchia solon*, and *Cranaena* n. sp. also occur in the lower part of this zone in the Andalusia Member at the Buffalo Quarry (Figs. 10, 11). The conodonts *Ancyrodella rugosa*, *A. africana*, *A. alta* (late form), and *Mesotaxis asymmetrica* occur high in the upper Andalusia Member at the Buffalo Quarry (Fig. 11). This conodont fauna in unit 16 (sample 21C, Figs. 10, 11) correlates directly with Zone 3 of the Frasnian Montagne Noire conodont sequence in southwestern France (Klapper, 1989; Day, 1990; Johnson and Klapper, 1992; Bunker and Witzke, this guidebook).

CORRELATION AND DISCUSSION

Central Missouri

The Little Cedar Formation of Iowa is correlated with strata bearing conodonts of the *varcus* and *hermanni* Zones (Schumacher, 1972, 1976) in the Devonian outcrop belt in central Missouri, placed by Witzke et al. (1989) in the lower and middle parts of the type Callaway Formation. It appears that strata equivalent to the Coralville Formation (upper T-R Cycle IIa, Johnson et al., 1985; Johnson and Klapper, 1992) were eroded in the region of the Devonian outcrop belt of central Missouri prior to the T-R Cycle IIb trangression in the latest Givetian (Witzke et al., 1985; 1989).

The *Allanella allani* Zone of Iowa is correlated with brachiopod and conodont faunas from the "upper" type Callaway Formation (sensu Witzke et al., 1989, fig. 14, p. 246-247), in Callaway County, Missouri. *Pandorinellina insita* occurs in this interval (Schumacher 1972, 1976). *Eosyringothyris occidentalis* occurs in the "upper" Callaway Formation as well as the Snyder Creek Shale (Branson, 1922, p. 103, pl. 20, figs. 3-5; Calvin Collection, Univ. of Iowa). In Iowa, *E. occidentalis* is restricted to strata of the *A. allani* Zone in the Andalusia Member at the Buffalo Quarry (Figs. 10, 11) and in the State Quarry Member at the Vanourney Quarry (*Allanella* Fauna, Figs. 17, 18).

Gregor (1909) and Branson (1922, 1944) illustrated most of the brachiopod fauna of the Snyder Creek Shale of central Missouri. Conodonts reported by Schumacher (1972) and Klapper (in Johnson and Klapper, 1992) from low in the Snyder Creek are similar to the upper Andalusia Member Montagne Noire Zone 3 fauna from the Lithograph City Formation in eastern Iowa (Figs. 10-12). On the evidence of its conodont and brachiopod faunas, the entire Snyder Creek Formation is considered the equivalent of the upper Lithograph City Formation of Iowa. Brachiopods common to both the Snyder Creek and Lithograph City faunas include: *Strophodonta (S.) callawayensis, S. (S.) inflexa, Devonoproductus reticulocostus, Hadrorhynchia solon, Allanella annae, Cyrtina* sp. A, *Tecnocyrtina missouriensis*, and *Eosyringothyris occidentalis*.

Michigan Basin

Wisconsin

The Little Cedar Formation of Iowa correlates with the Berthelet and Lindwurm members of the Milwaukee Formation of southeastern Wisconsin (Raasch, 1935). Two thirds of the 43 species of brachiopods described from the Berthlet and Lindwurm members (Cleland 1911; Greisemer, 1965) also occur in the Little Cedar Formation of Iowa. The following species from Wisconsin T-R Cycle IIa strata are the same or closely similar to Little Cedar taxa: *Athyris vittata, Cyrtina triquetra, C. umbonata, Elita subundifera, Orthospirifer iowensis, Seratrypa* sp. A, *S.* sp. B, *Tylothyris subvaricosa, Pholidostropia iowensis, Striatochonetes schucherti, Strophodonta (S.) halli, Cranaena cooperi,* and *Pentamerella multicosta*. Conodont (Schumacher, 1971; Kluessendorf et al., 1989) faunas known from the upper part of the Berthlet and Lindwurm members indicate a correlation of these strata with the *hermanni* Zone (Schumacher, 1971; Carman, in Kluessendorf et al., 1989). Strata of the underlying lower-middle Berthlet contain brachiopods indicating correlation with the Solon Member of the Little Cedar Formation of Iowa. Little is known of the brachiopod and conodont fauna of the North Point Member of the Milwaukee. By position above T-R Cycle IIa strata of the Berthelet and Lindwurm members the North Point could correlate with strata of the Coralville or T-R Cycle IIb strata of the Lithograph City Formation.

Lower Peninsula of Michigan

Bunker and Witzke (this guidebook) have postulated correlations of Cedar Valley strata with the Traverse Group of western Michigan as follows: 1) upper Gravel Point-Charlevoix and Little Cedar, 2) Petosky and Coralville, 3) Whisky Creek and lower Lithograph City, and 4) Jordan River-Squaw Bay and the upper Lithograph City. Elements of the brachiopod faunas of the foregoing units in Michigan are still relatively poorly understood, although studies by Ehlers and Kesling (1970) and Kesling et al. (1974, 1976) indicate that similarities certainly exist between the Cedar Valley and Traverse successions.

At this time, the brachiopod faunas illustrated from the Gravel Point and Charelvoix formations are not sufficient to provide detailed correlations of this interval in Michigan with the Little Cedar of Iowa, although Kesling et al. (1974) did illustrate species of *Seratrypa* (ibid., see *Atrypa corrugata*, pl. 3, figs. 1-6), *Strophodonta (S.), Cranaena*, and *Pentamerella* that have closely related Little Cedar counterparts in Iowa. *Pentamerella petoskyensis* (Kesling et al., 1974, pl. 10, figs. 13-18, considered by this author as a junior synonym of *P. dubia*) occurs in the Petosky Formation, which is now correlated with part of the *disparilis* Zone based on the occurrence of the conodont *Klapperina disparalvea* from the basal Petosky (Bunker and Witzke, this guidebook). *Pentamerella dubia* is restricted to the Cou Falls Member of the Coralville Formation, and occurs with conodonts of the Upper *subterminus* Fauna in Iowa. The postulated correlation of the Whiskey Creek Formation with the lower Lithograph City Formation is based on: 1) position of the Whiskey Creek above strata of the Petosky, correlated with part of the *disparilis* Zone, and 2) position below strata of the Jordan River that do contain *Allanella* cf. *A. allani* (illustrated as *Mucrospirifer* sp. by Kesling et al., 1974, pl. 13, figs. 10-21). The occurrence of *A.* cf. *allani* (Kesling et al., 1974) from the Jordan River suggests correlation with part of the *Allanella allani* Zone of the Lithograph City Formation. Species of *Ancyrodella* and *Mesotaxis* illustrated by Müller and Clark (1967) and Bultynck (1976) from the "Molluscan bed" and "Calcareous mudstone beds" (Gutschick and Sandberg, 1991) of Squaw Bay Formation indicate a correlation with the upper Lithograph City conodont faunas correlated with Zone 3 of the Montagne Noire Frasnian conodont sequence (Klapper, 1989).

Great Basin-Nevada

Brachiopod and conodont sequences of the Cedar Valley Group of Iowa (Fig. 3) can be correlated with late Givetian and Frasnian Faunal Intervals of the Great Basin standard Devonian sequence (Johnson, 1977, 1978, 1990; Johnson et al., 1980; Johnson and Trojan, 1982; Johnson et. al., 1985). The *Independatrypa independensis* and Lower *Rhyssochonetes bellarugosis* Zones (Figs. 3, 5, 6) correlate with Faunal Interval (F.I.) 21 of the Great Basin Devonian. Faunal Interval 21 was defined (Johnson, 1977, 1978, F.I. 21 on the basis of the occurrence of brachiopods of the *Rhyssochonetes* and *Devonoproductus* communities, containing *R. solox* with *Echinocoelia careocamera*, and upper Middle *varcus* Subzone conodonts.

The Upper *Rhyssochonetes bellarugosis* and Lower *Neatrypa waterlooensis* Zones of Iowa (Figs. 3, 5, 6) correlate with Faunal Intervals 23 and 24, respectively, of Johnson (1990, figs. 2, 49, 50), on the basis of the occurrence of brachiopod faunas of F.I. 23 and 24 with conodonts of the *hermanni* Zone (Johnson, ibid.). Johnson (1990, fig. 50) does show the first entry of *Rennselandia* sp. in F.I. 23 (Upper *Stringocephalus* Fauna of Johnson et al., 1980) which is mirrored by first occurrences of species of this genus in the lower Rapid interval in Iowa (Fig. 6). The base of the *Neatrypa waterlooensis* Zone is tentatively correlated with a position corresponding to the lower *hippocastanea* Fauna (F.I. 24) in the Nevada brachiopod sequence, which occurs in association with conodonts of the Upper *hermanni* Subzone (Klapper and Johnson, 1990, fig. 52). Brachiopods of F.I. 25 and 26, in association with conodonts of the Lower *disparilis* Subzone, of the Great Basin are correlated with the brachiopod fauna of the upper part of the *Neatrypa waterlooensis* Zone of the upper Rapid Member of eastern Iowa (Figs. 3, 6). As mentioned earlier, the brachiopod fauna of the Upper *Neatrypa waterlooensis* Subzone of Iowa occurs with conodonts of the Lower *subterminus* Fauna (correlated with the Lower *disparilis* Zone by Witzke et al., 1989).

Day (1989a, b) correlated the *Strophodonta plicata* Zone (now = *Tecnocyrtina missouriensis missouriensis* Zone) of the Coralville Formation with Faunal Interval 27 of the Nevada Devonian brachiopod succession (lower *Tecnocyrtina* Fauna of Johnson and Trojan, 1982), based on the occurrence of *Tecnocyrtina missouriensis missouriensis* in the Gizzard Creek Member of the Coralville Formation. The closely related species *T. m. teleta* and *T. fissiplicata* make first appearances in F.I. 27 in Nevada (Johnson and Trojan, 1982; Johnson, 1990). Johnson and Trojan (1982) and Johnson et al. (1985, fig. 2) correlated F.I. 27 in Nevada with the upper part of the *disparilis* Zone.

The brachiopods *Tecnocyrtina fissiplicata, Ladogioides pax, Allanella layeri, Variatrypa (R.) klukasi,* and *Spinatrypina augusticostata* occur with the conodont *Pandorinellina insita* in strata in the Antelope Range of central Nevada and were correlated by Johnson and Trojan (1982) with Faunal Interval 28. These strata are now considered to correlate with the *norrisi* Zone (Johnson, 1990). The *Allanella allani* Zone correlates with Faunal Interval 28 (F.I. 28, Upper *Tecnocyrtina* fauna) of the standard faunal sequence in the Devonian of the Great Basin. The *Strophodonta (S.) callawayensis* Zone of Iowa is correlated (Day, 1989a) with Faunal Interval 29 of the Great Basin Devonian (Johnson et al., 1980; Johnson, 1990).

Southern New Mexico

Cooper et al. (1942), Johnson (1970), Cooper and Dutro (1982), and Day (1988) noted the close relationship of the fauna of the Oñate Formation of southern New Mexico with "Lower Taghanic" strata and faunas based on the occurrence of species of *Rhyssochonetes* in faunas with Middle *varcus* Zone conodonts in eastern and western North America. Cooper and Dutro (1982) correlated the Oñate with the entire Cedar Valley Limestone/Formation of Iowa (now =Little Cedar and Coralville Fms.) and Tully Formation of New York based on the shared occurrences of species of the brachiopods *Rhyssochonetes, Hypothyridina,* and the byrozoan *Sulcoretopora*, among others, in the aforementioned areas.

Day (1988, 1989c) defined a brachiopod zonation based on the brachiopod sequence in the Oñate Formation, and revised correlations of the Oñate with other Middle Devonian successions throughout North America. The brachiopod zonation of the Oñate (Day, 1988, 1989c) consists of (in ascending order): the *Rhyssochonetes johnsoni*, *Striatochonetes nanus*, *Dichacaenia umbonata*, and the *Warrenella magna* Zones. The *Independatrypa independensis* and Lower *Rhyssochonetes bellarugosis* Zones of Iowa are correlated with the interval of the *Rhyssochonetes johnsoni* and *Striatochonetes nanus* Zones in the Oñate Formation of southern New Mexico. The *Striatochonetes nanus* Zone of New Mexico is defined by the first occurrence of *S. nanus* and is characterized by the occurrence of *Rhyssochonetes johnsoni* with *S. nanus*, below the entry of *Dichacaenia umbonata* (Day, 1988). In Iowa, *Rhyssochonetes bellarugosis* occurs in association with *Striatochonetes schucherti* in the Lower *R. bellarugosis* Zone of the upper Solon Member, below the entry of the first *Dichacaenia* (*D. harberti*) at the base of the Upper *R. bellarugosis* Zone.

The *Dichacaenia umbonata* Zone of New Mexico correlates with the Upper *Rhyssochonetes bellarugosis* Zone of the lower Rapid Member of the Little Cedar Formation. This correlation is based on the first occurrence of *Dichacaenia harberti* above the highest occurrence of *Rhyssochonetes* in the latter interval in Iowa, which mirrors the order of appearance of species of the aforementioned genera in the Oñate sequence in New Mexico (Day, 1988). Collectively, the *D. umbonata* and *Warrenella magna* Zones of the New Mexico Devonian sequence correlate with the Upper *Rhyssochonetes* and *Neatrypa waterlooensis* Zones (entire Rapid Member) of Iowa. No brachiopod or conodont faunas comparable to those of the *Tecnocyrtina missouriensis* Zone and Upper *subterminus* Fauna of the cratonic interior occur in New Mexico. The remainder of the Devonian strata of New Mexico are of late Frasnian and Famennian age and their correlations are discussed in works by Cooper and Dutro (1982) and Day (1988, 1989a, 1989c, 1990).

Appalachian Basin-New York

The brachiopod faunas in what is now the Little Cedar and Coralville formations (=Cedar Valley Limestone prior to 1983) have historically provided the basis for older correlations of these units with the Tully Formation of New York (Cooper and Williams, 1935; Cooper et al., 1942; Cooper, 1967; Johnson, 1970; Johnson et al., 1985). The Little Cedar Formation of Iowa is correlated with T-R Cycle IIa equivalents included in the Tully (upper part of the Lower and Upper Tully) and part of the Geneseo Shale and Leicester Pyrite of the Genesse Formation based on conodont faunas reported from these units (Huddle, 1971; Kirchgasser et al., 1986, 1989). The Coralville Formation is tentatively correlated here with the Fir Tree limestone of the Genesse Formation based on the correlation of Fir Tree conodonts (*ordinatus* Fauna of Kirchgasser et al., 1989, figs. 2, 3) with the upper part of the *disparilis* Zone.

Conodonts reported from the Lodi Limestone and Penn Yann Shale members of the Genesee Formation by Huddle (1981), Klapper (1981), Kirchgasser et al. (1986, 1989) suggest correlation of the lower Lithograph City Formation with strata of the Lodi and Penn Yann below the entry of the *Ancyrodella rotundiloba* fauna as shown in fig. 3 of Kirchgasser et al. (1989). Strata of the upper Lithograph City Formation (Fig. 3, upper Andalusia Member correlated with Montagne Noire Zone 3) correlate with the upper Genundewa Limestone and lower part of the West River Shale members of the Genesee based on the occurrence of the late form of *Ancyrodella alata* as shown earlier in fig. 3 of Kirchgasser et al. (1989), and more precise data on the range of *A. alata* (late form) reported by Kirchgasser and Klapper (1992).

Western Canada-Alberta

The *Tecnocyrtina missouriensis* Zone of the Coralville Formation can be easily correlated with strata of the Slave Point Formation in northeast Alberta and the Great Slave Lake area of the southern Northwest Territories that contain conodonts of the Upper *subterminus* Fauna as shown in fig. 2 of Braun et al. (1989). *Allanella allani* Zone is correlated with the fauna of the upper Slave Point Formation on Lake Claire in northeastern Alberta assigned to the *Tecnocyrtina billingsi* Zone (Pedder, in Lenz and Pedder, 1972, p. 37; Norris and Uyeno, 1981, p. 7 with conodonts of the *insita* Fauna. Day (1989a) correlated the lower part of the Lithograph City Formation, now encompassed by the *Allanella allani* Zone, with the Firebag and middle and upper parts of the Calumet Member of the Waterways Formation of the Clearwater rivers area of Northeastern Alberta based on the occurrence of *Schizophoria lata*, *S.* cf. *S. athabaskensis*, and *Strophodonta* (*S.*) *albertensis* (Norris, 1983) in the Calumet Member (Day, 1989a). The latter species is considered by this author to be a junior synonym of *S.*

(*S.*) *iowensis* of the State Quarry and Andalusia members of the Lithograph City Formation of Iowa.

Norris and Uyeno (1981) reported brachiopod faunas in association with conodonts correlated with the *norrisi* Zone (= former Lowermost *asymmetricus* Zone) and "Lower *asymmetricus* Zone" from the Waterways Formation in the Birch River and Powell Creek area of the District of Mackenzie in northeastern Alberta. The *Allanella allani* Zone of Iowa is correlated with the faunas of Units I, II, and III of the Calumet Member (fig. 3, p. 10, Norris and Uyeno, 1981). These units contain *Ladogioides asmenista, Radiatrypa clarkei, Spinatrypina* sp., *Athyris parvula, Allanella minutilla,* and *Schizophoria lata.* Norris and Uyeno (1983) reported *Ladogioides pax, Variatrypa (Radiatrypa) klukasi, Schizophoria lata, Tecnocyrtina billingsi,* and *Eleutherokomma impennis* (considered by this author as a synonym of *Allanella annae*) with conodonts of the *insita* Fauna in the Peace Point Member of the Waterways Formation in the Gypsum Cliffs area of Northeastern Alberta, and are correlated directly here with the *Allanella allani* Zone of the Iowa Devonian sequence.

Elk Point/Williston Basin Manitoba and Saskatchewan

Late Givetian-early Frasnian strata of Iowa and southern Manitoba display closely comparable relative sea-level histories, as well as closely similar conodont and brachiopod sequences, which suggest close paleogeographic connections between these two cratonic basins during major transgressive episodes (T-R Cycles IIa, IIb, IIc of Fig. 3). Norris et al. (1982) suggested correlations between the two regions, which were later revised by Witzke et al. (1989) and Day et al. (1991). The following discussion is based on recent correlations discussed in Witzke et al. (1989), Braun et al. (1989), and Day et al. (1991), which incorporates unpublished data of the author on the brachiopod and conodont sequences in Souris River Formation of the Manitoba Group.

The Little Cedar Formation correlates with the Dawson Bay Formation of Manitoba, which has been suggested by numerous authors including McCammon (1960), Johnson (1970), Norris et al. (1982), Cooper and Dutro (1982), Johnson et al. (1985), Day (1988), Witzke et al. (1989), and Day et al. (1991). The newly revised Cedar Valley Group stratigraphy (Witzke et al., 1989), and proposed brachiopod zonation (combined with the known conodont sequence) of the Little Cedar Formation allows for refined correlations of these two closely related successions.

The *Independatrypa independensis* and Lower *Rhyssochonetes bellarugosis* Zones of the Solon Member of Iowa are correlated with the fauna of Member B and part of Member C of the Dawson Bay Formation of Manitoba. The *I. independensis* Zone correlates with strata of the lower half of Member B of the Dawson Bay containing the brachiopods *Independatrypa snakensis, Pseudoatrypa bremerensis,* and *Spinatrypa mascula* (McCammon, 1960; Norris et al., 1982; author's collections) with conodonts of the Middle *varcus* Subzone (Norris and Uyeno, 1971; Uyeno, *in* Norris et al., 1982; Braun et al., 1989; Day et al., 1991). The occurrence of *Rhyssochonetes aurora* with conodonts of the *varcus* Zone in upper Member B and Member C of the Dawson Bay Formation (p. 55-56, Norris et al., 1982) is tentatively correlated with the Lower *Rhyssochonetes bellarugosis* Zone of Iowa. The Upper *R. bellarugosis* Subzone and *Neatrypa waterlooensis* Zone of Iowa are tentatively correlated with Dawson Bay strata above the range of *R. aurora* (upper Member C and Member D). Member D (Dawson Bay Fm.) strata above the lowest occurrence of *Icriodus subterminus* (=base of Lower *subterminus* Fauna; Norris and Uyeno, 1982, p. 56) are correlated with the Upper Rapid and Eagle Center members of the Little Cedar Formation of Iowa (upper part of the *Neatrypa waterlooensis* Zone) containing conodonts of the Upper *subterminus* Fauna (Fig. 3).

The *Tecnocyrtina missouriensis* Zone of Iowa is correlated directly with the lower "Argillaceous limestone beds" of the Point Wilkins Member of the Souris River Formation. The latter strata contain conodonts of the Upper *subterminus* Fauna in association with the brachiopods *Cranaena iowensis* (Norris et al., 1982; Braun, et al. 1989; Day et al. 1991), and *Tecnocyrtina missouriensis missouriensis* reported here. The *Allanella allani* Zone of the Lithograph City Formation is correlated directly with strata and faunas of the Micritic limestone beds of the Point Wilkins Member of the Souris River Formation that contain *Allanella allani* with *Skeletognathus norrisi* and *Pandorinellina insita* (Norris et al., 1982; Day et al, 1991; author's samples). The upper part of the Micritic limestone beds (above the last *Skeletognathus norrisi*) and Dolomitic limestone beds of the Point Wilkins Member are correlated with the *Strophodonta (S.) callawayensis* Zone of Iowa. The Sagemace Member of the Souris River Formation, separated from subjacent strata of the Point Wilkins Member by a pronounced unconformity, is correlated with the Shell Rock Formation of northern Iowa (Witzke et al., 1989; Day et al., 1991.). In Saskatchewan, the *Allanella allani* Zone is correlated with Unit B of the Davidson Member of the Souris River Formation that contains *Radiatrypa clarkei*, *Independatrypa independensis*, *Allanella allani*, *Athyris vittata*, and *Schizophoria* sp. (Norris et al., 1982).

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APPENDIX

Locations and descriptions of measured sections and fossil localities of Cedar Valley Group strata, central and eastern Iowa. Locations of measured sections shown in Figures 2, 4, 7, 8, 10, 14, 15, and 18. All unit intervals are in meters above base of section, all sample elevations are in meters above base of section, or above/below unit contacts.

HANNEMAN QUARRY 1991 (HNQ91)

LOCATION: located C, NE, NE, Section 20, T94N, R15W, four miles west of the town of Nashua, Floyd County, Iowa. Lower half of section measured on east high wall, upper half of section measured on west face across the quarry.
MEASURED: 8/14/91 by Jed Day.

UNIT INTERVAL UNIT DESCRIPTION

LITHOGRAPH CITY FM.
OSAGE SPRINGS MB.

1 0.00-1.00 COVERED INTERVAL
2 1.00-1.27 MUDSTONE: light brown, very fine grained, laminated, dolomitic.
3 1.27-1.36 SHALE: med. gray, calcareous.
4 1.36-2.20 MUDSTONE: med.-lt. brown, med.-thick bedded, occurs as six beds (5-25 cm), laminated, with scattered burrow structures, scattered angular mudstone intraclasts in upper 5 cm of lowermost bed of unit (20 cm), upper 5 cm consists of lt. gray-brown calcareous shale.
5 2.20-3.00 INTRAFORMATIONAL CONGLOMERATE & MUDSTONE: lower 12 cm consists of mudstone intraclast conglomerate, laminated in upper 5 cm; upper 68 cm consists of laminated platey lithographic mudstone.

IDLEWILD MB.

6 3.00-3.30 SHALE: med. gray-brown, calcareous.
7 3.30-3.55 MUDSTONE: med.-lt. brown, laminated, mudcracks with small intraclast fills.
8 3.55-3.65 SHALE: same as unit 6.
9 3.65-3.93 MUDSTONE: lower 5-10 cm consists of argillaceous-platey mudstone; upper 18-23 cm consists of lithographic dolomitic mudstone.
10 3.93-4.05 SHALE: lt. brown, calcareous, with thin (5-10 mm) lime mud stringers.
11 4.05-6.53 MUDSTONE: lt. brown, laminated-ripple laminated dolomitic mudstone, lithographic in some intervals, with mudcrack horizons, scattered mudstone intraclasts in upper 10-15 cm.
12 6.53-6.78 SILTSTONE/SHALE: lt. brown, very argillaceous siltstone-silty shale, weathers to angular blocks, calcareous.
13 6.78-6.93 MUDSTONE: lt. brown, laminated, with scattered subangular-subrounded mudstone intraclasts, ostracodes.
14 6.93-7.05 SHALE/SILTSTONE: same as unit 12.
15 7.05-8.27 MUDSTONE- INTRAFORMATIONAL CONGLOMERATE: laminated, dolomitic mudstone, with intervals with scattered angular mud intraclasts, and intervals consisting of thin (2-10 cm) intraclast conglomerates.

MARINE FLOODING SURFACE AT CONTACT

16 8.27-8.87 SKELETAL WACKE-PACKSTONE: occurs as four beds from 5-30 cm, whole and abraded skeletal grains abundant, with *Allanella* n. sp., *Athyris vittata*, *Pseudoatrypa*? *lineata*, gastropods, bivalves, echinoderms, branching and small hemispherical stromatoporoids. Conodont Sample: HNQ91-1C @ 8.70-8.75 cm.
17 8.87-8.99 SHALE: lt. brown, calcareous, fossiliferous, with same fauna as unit 16.
18 8.99-9.74 SKELETAL WACKESTONE-FRAMESTONE: occurs as two beds; lower bed (45 cm) consists of skeletal wackestone with echinoderm grains, branching stromatoporoids, gastropods, with *Allanella* n. sp. *Athyris vittata*, and *Pseudoatrypa*? *lineata*; the upper bed (35 cm) consists of a branching and hemispherical stromatoporoid framestone, with large gastropods, bivalves, *Allanella* n. sp., *Floweria altirostris*, *Athyris vittata*, and *Pseudoatrypa*? *lineata*. Megafossil Sample: included in HNQ-85, HNQ-90, and HNQ-91 that consist of elements of fauna from units 18 and 19.
19 9.74-10.09 NODULAR SHALE: lt. gray-brown, calcareous, extremely fossiliferous, with scattered skeletal mudstone nodules, contains abundant *Pseudoatrypa*? *lineata*, *Athyris vittata*, *Allanella* n. sp., with *Floweria altirostris*, *Cranaena infrequens*, *Strophodonta inflexa*, *Strophodonta scottensis*, *Strophodonta moberliensis*, *Schizophoria* sp., and *Gypidulina* sp.
20 10.09-10.29 SKELETAL MUDSTONE /WACKESTONE: skeletal mudstone, fauna undocumented.

GLORY QUARRY 1991 (GLQ91)

LOCATION: located in NW, SE, NW, Section 36, T87N, R11W, in the southwest corner of Black Hawk County, Iowa. Section measured on the northwest face of quarry highwall, starting at water level.
MEASURED: 7/86 by Jed Day and Fred Rogers, remeasured and sampled 8/14/91 by Jed Day.

UNIT INTERVAL UNIT DESCRIPTION

LITTLE CEDAR FM.
EAGLE CENTER MB. (10.10 m)

1 0.00-1.65 SKELETAL CALCISILTITE/WACKESTONE: medium gray-brown, massive-thick bedded, wave laminations, burrowed, argillaceous,

with scattered chert nodules (up to 60 cm) in the lower meter, more abundant in the upper 60 cm, contains ramose bryozoans, echinoderms, brachiopods, *Orthospirifer parryanus* at 95 cm. Conodont Samples: GLQ91-1C @ 55-65 cm, GLQ91-2C @ 145-155 cm above base of unit 1. Megafossil Sample: GLQ91-Float Unit 1 from entire unit.

2 1.65-3.75 SKELETAL CALCISILTITE /WACKESTONE: platy argillaceous, laminated, extremely bioturbated, with thin chert stringers and nodules, contains brachiopod and echinoderm grains.

3 3.75-3.90 SKELETAL GRAINSTONE: Medium blue-gray, abundant echinoderm and brachiopod grains, large replacement chert nodules replacing entire thickness of unit along strike. Contains *Tylothyris subvaricosa*, *Neatrypa waterlooensis*, *Echinocoelia halli*, *Pseudoatrypa* sp. *Cupularostrum cedarensis*, *Cyrtina triquetra*. Megafossil and Conodont Sample: GLQ91-3CF @ 3.75-3.90 cm.

4 3.90-5.20 SKELETAL WACKESTONE: thick bedded-massive, bioturbated, abundant scattered replacement chert nodules in lower 75 cm, prominent bedded chert at 75 cm and 155 cm above base of Unit. Fauna includes: echinoderms, the brachiopods *Neatrypa waterlooensis*, *Tylothyris* sp., *Pseudoatrypa* sp., *Orthospirifer iowensis*, and *Athyris vittata*. Conodont Sample: GLQ91-4C @ 425-445 cm.

5 5.20-6.00 SKELETAL GRAINSTONE & WACKESTONE: three skeletal grainstone beds with skeletal wackestone interbeds make up lower 40 cm of unit; upper 40 cm consist of burrowed skeletal wackestone. Replacement chert nodules scattered in upper 40 cm with prominent massive discontinuous chert band in upper 10 cm of unit, scattered solution vugs with calcite cement fills. Conodont Sample: GLQ91-Unit 5 @ 530-550 cm. Megafossil Sample: GLQ91-5CF @ 515-555 cm.

6 6.00-8.60 SKELETAL WACKE-MUDSTONE: laminated, burrowed mudstone, with scattered replacement chert nodules in most of unit, upper 10-15 cm consists of a prominent bedded chert, skeletal grains and scattered spar-filled solution vugs restricted to lower 185 cm of unit, absent (visually) from upper 75 cm. Lower 20-30 cm are intensely bioturbated, upper 60 cm are finely laminated with scattered burrow structures.

7 8.60-10.10 MUDSTONE: mottled, massive, silty, laminated, dolomitic, with rare scattered burrows, little or no chert nodules.

HINKLE MB. (1.78 m)

8 10.10-10.40 MUDSTONE: lt. brown-tan, lithographic, with conchoidal fracture, unfossiliferous.

9 10.40-10.67 MUDSTONE-WACKESTONE: lt. brown, lower 12 cm with scattered angular lime mud intraclasts, upper 10 cm with scattered intraclasts, stromatolitic laminations, and birdseye structures.

10 10.67-11.38 BINDSTONE: algal laminated stromatolitic bindstone fine laminations in lower 32 cm, thin algal lams in upper 39 cm.

11 11.38-11.88 BINDSTONE: algal laminated stromatolitic bindstone, with scattered sand-pebble sized subangular intraclasts throughout unit.

CORALVILLE FM.
GIZZARD CREEK MB.

12 11.88-12.58 SKELETAL DOLOMITE: massive skeletal dolo-wackestone, with fossil molds, and open secondary solution vugs, with echinoderm and brachiopod grains evident, contains *Athyris vittata*. Conodont Sample: GLQ91-7C @ 1188-1200 cm.

13 12.58-13.48 SKELETAL DOLOMITE: two thick to massive beds; lower 55 cm consists of massive skeletal dolo-wackestone, with echinoderms, brachiopods, and scattered idiostromid branching stromatoporoids, containing *Independatrypa randalia* and *Athyris vittata*; the upper 35 cm consist of a skeletal dolo-packstone to grainstone with large open secondary solution vugs with silicified skeletal grains, contains same fauna as underlying part of unit. GLQ91-7F from upper 20 cm of unit.

14 13.48-13.88 SKELETAL DOLO-PACK /BOUNDSTONE: a single thick bed of dolomitized skeletal pack-boundstone, with framework provided by small-large hemispherical actinostromid stromatoporoids, branching idiostromid stromatoporoids, and aveolitid tabulate corals, originally with lime mud matrix containing abundant brachiopod and echinoderm grains. Contains abundant *Independatrypa randalia*, with *Athyris vittata* and *Tecnocyrtina missouriensis missouriensis*. Megafossil Sample: GLQ-Gizzard Creek Fauna-large float collections made from units 14 & 15.

15 13.88-13.98 SKELETAL DOLOMITE: dolomitized skeletal wacke-packstone, with abundant brachiopod and echinoderm grains, with branching idiostromid stromatoporoids. Contains abundant *Independatrypa randalia*, with *Seratrypa rotunda*, *Athyris vittata*, and rare *Tecnocyrtina missouriensis missouriensis*. Conodont Sample: GLQ91-8C @ 1388-1398 cm. Megafossil Sample: GLQ-Gizzard Creek Fauna-large float collection from units 14 & 15.

VANOURNEY QUARRY 1991 (VQ91)

LOCATION: SE, SW, SW, Section 26, T81N, R6W, on north side of Vanourney Quarry, approximately 75 m south of gate. Section started immediately below large exposed bench on top of Unit 3. **MEASURED:** 5/22/91, by Jed Day, with Jim Kralick, and Greg Ludvigson.

UNIT INTERVAL   UNIT DESCRIPTION

LITTLE CEDAR FM.
RAPID MB.

1 0.00-3.02 ARGILLACEOUS-SILTY SKELETAL WACKE-PACKSTONE: very argillaceous, silty, recessive, weathers as plates, mostly wackestone with packstone skeletal lags, very fossiliferous. Contains *Pseudoatrypa* sp., *Neatrypa waterlooensis, Orthospirifer parryanus, O. iowensis, Devonochonetes* sp., *Tylothyris* sp., *Athyris vittata, Spinatrypa (S.) bellula, Cyrtina* sp., *Schizophoria* sp., *Strophodonta (S.)* sp., with abund. echinoderms, branching ramose and fenestrate bryozoans, *Platyceras* sp. and other conspiral gastropods, bivalves, solitary tetracorals, *Favosites* sp., *Aulopora* sp. and other tabulate corals. Megafossil Sample: VQ91-Float Unit 1 from entire unit.

2 3.02-3.52 SHALE-NODULAR MUDSTONE: recessive med. gray brown shale with skeletal mudstone nodules, burrowed, very fossiliferous with *Schizophoria* sp., *Strophodonta (S)*. sp., echinoderms. Megafossil Sample: VQ91-Unit 2 from entire unit.

3 3.52-4.67 SKELETAL PACKSTONE: occurs as two major beds, consisting of a lower 25 cm bed, a 10 cm shale interbed, and a massive upper 80 cm bed. Upper surface of unit with abundant articulated oriented echinoderm pelmas and cladoporid tabulate corals. Shale interbed contains abundant solitary tetracorals, branching favositid tabulate corals, echinoderms and brachiopods. Lower and upper packstone beds, contain an abundant fauna with large hemispherical favositid tabulates and solitary tetracorals, with brachiopod and bryozoan fauna similar to that of Unit 1. Megafossil Samples: VQ91-Unit 3 Float-loose material collected on upper surface of Unit 3, VQ91-Slabs from Unit 3 consists of in-place slabs taken from upper 5 cm of Unit 3.

4 4.67-5.07 SHALE: largely covered.

5 5.07-5.47 SKELETAL PACK-WACKESTONE: grain types include solitary and colonial tetracorals, hemispherical favositid tabulate corals, branching ramose and fenestrate bryozoans, brachiopods and echinoderms. Conodont Sample: VQ91-1C taken from upper 15 cm of Unit 5. Megafossil Sample: VQ91-Top Unit 5 taken from upper 10 cm of Unit 5.

LITHOGRAPH CITY FM.
STATE QUARRY MB.

6 5.47-7.42 SKELETAL-INTRACLAST PACKSTONE: cross-bedded in sets from 5-25 cm thick, cross-bedding progrades from right to left when looking north at face of exposure. Echinoderm, intraclasts, and brachiopods (*Allanella allani, Athyris vittata, Pseudoatrypa rugatula*) are most abundant grain types, with articulated calices of crinoids visible. Solitary and colonial tetracorals restricted to lower bed of unit and appear to be reworked from upper part of the Rapid Member. Grain sizes appear to decrease from base to upper part of unit. Conodont Sample: VQ91-2C lower 15 cm of Unit 6.

7 7.42-7.87 SKELETAL-INTRACLAST PACKSTONE: grain types as below, although intraclasts and mud matrix more abundant, except in upper 15 cm where brachiopod grains are abundant and form solid pavements consisting almost entirely of *Allanella allani,* with rare *Eosyringothyris occidentalis* and *Athyris vittata.* Glacial striations present on upper surface of unit. Conodont Sample: VQ91-3C taken from upper 20 cm of Unit 7. Megafossil Samples: VQ91-Float Unit 7 consists of isolated specimens of brachiopods taken from upper surface of unit, VQ91-Slabs from Unit 7 consists of in-place slabs with brachiopods taken from upper 15 cm of Unit 7.

INDIAN CAVE 1991 (IC91)

LOCATION: section of uppermost Rapid Mb., Little Cedar Fm., Cou Falls Mb. Coralville Fm., State Quarry Mb., Lithograph City Fm., located on north side of stream valley at Indian Cave archaeological site, in the N 1/2, NW, NW, Section 30, T80N, R5W, Johnson County, Iowa.
MEASURED: 5/91 by Jed Day, Greg Ludvigson, and Jim Kralick.

UNIT INTERVAL   UNIT DESCRIPTION

LITTLE CEDAR FM.
RAPID MB.

1 0.00-1.25 SKELETAL PACK-WACKESTONE: med. brown, argillaceous, occurs as single bed, fractured-platy, very fossiliferous, with large branching favositid tabulate corals, solitary and colonial tetracorals, echinoderm grains, and brachiopods. Contains *Favosites* sp., *Tabulophyllum* sp., *Neatrypa waterlooensis, Schizophoria* sp., *Tylothyris* sp., *Orthospirifer iowensis.*

CORALVILLE FM.
COU FALLS MB.

2 0.00-0.75 SKELETAL WACKE-PACKSTONE: med. brown gray, with overturned and upright coralums of the colonial tetracoral *Hexagonaria*, the tabulate coral *Favosites*, solitary tetracorals, the brachiopods *Pseudoatrypa* sp., *Neatrypa waterlooensis, Pentamerella* sp., *Cranaena iowensis, Tylothyris* sp., echinoderm ossicles, gastropods, and rostroconchs. Lithologic/ Isotope Sample: IC91-0L taken @ 55 cm above base of Unit 2. Conodont Sample: IC91-1C taken from 55-75 cm above base of Unit 2.

LITHOGRAPH CITY FM.
STATE QUARRY MB.

3 0.75-1.75 SKELETAL PACK-GRAINSTONE: a single massive bed with oxidized-argillaceous stylolitic partings, major grains include echinoderms, gastropods, brachiopods, sand-sized and rounded micrite intraclasts, with mud or spar matrix. Contains abundant *Pseudoatrypa rugatula, Cyrtina* sp. A, *Tecnocyrtina* n. sp., with *Cranaena depressa, Athryis vittata, Allanella allani*, phaceloid tetracorals, small hemispherical and tabular stromatoporoids, and laminar stromatoporoids in upper part of unit. Lithologic/Isotope Sample: IC91-1L taken at 10 cm above base of Unit 3. Conodont Sample: IC91-2C from lower 20 cm of unit. Megafossil Sample: IC91-1F from lower 15 cm, IC91-2F from upper 20 cm.

4 1.75-2.45 SKELETAL GRAIN-PACKSTONE: occurs as three beds, lower bed 50 cm, upper two beds 10 cm each, major grain types as in unit 3. Contains *Pseudoatrypa rugatula, Cranaena depressa, Allanella allani, Tecnocyrtina* n. sp., *Hadrorhynchia solon, Cyrtina* sp. A with rare *Eosyringothyris occidentalis*, small hemispherical and tabular actinostromid, and branching amphiporid stromatoporoids. Lithologic Sample: IC91-2L taken from top 20 cm of Unit 4. Conodont Sample: IC91-3C taken from top 20 cm of unit. Megafossil Sample: IC91-3F taken from top 20 cm of unit.

5 2.45-3.30 SKELETAL GRAIN-PACKSTONE: massive bed, with argillaceous stylolitic partings, major grain types as in underlying units. *Allanella allani* very abundant, with small *Cranaena depressa, Athyris vittata, Pseudoatrypa rugatula*, and branching amphiporid stromatoporoids. Megafossil Sample: IC91-4F taken from upper 20 cm of Unit 5.

6 3.30-4.51 SKELETAL PACK-GRAINSTONE: consists of three thin platy beds in lower 30 cm, overlain by massive bed (71 cm), with two thin beds (10 cm each) at top of unit. Contains abundant *Allanella allani*, with *Cranaena depressa, Athyris vittata*; branching amphiporid stromatoporoids in lower beds, absent in upper part of unit. Lithologic/Isotope Samples: IC91-3L taken from lower 10 cm, IC91-4L from 101-111 cm above base of unit. Conodont Samples: IC91-4C taken from lower 20 cm, IC91-5C from upper 20 cm of unit. Megafossil Samples: IC91-5F taken from 10-20 cm, and IC91-6F taken from 100-115 cm above base of unit.

7 4.51-5.21 SKELETAL PACK- GRAINSTONE: occurs as six thin beds separated by stylolitic surfaces, contains brachiopod, echinoderm, and rounded intraclasts. Lithologic/Isotope Sample: IC91-5L taken in upper 10 cm of Unit 7. Conodont Sample: IC91-6C taken in upper bed (10 cm) of unit.

BUFFALO QUARRY 1991-1 (BQ91)

LOCATION: located in the W 1/2, NE, NW, NE, Section 23, T77N, R2E, Scott County, Iowa. Located 300 m west of section measured by Witzke and Bunker (1985, Appendix), located on north side of Davenport Cement Company Quarry, just north of new cross-quarry ramp being built to conveyer system.
MEASURED: BQ91/2 measured 6/21/91 by Jed Day and Dennis Haas.

<u>**UNIT INTERVAL DESCRIPTION**</u>

CORALVILLE FM.
COU FALL MB.

1 0.00-0.54 SKELETAL WACKE-PACKSTONE: light brown, with laminar stromatoporoids in lower 30 cm above burrowed discontinuity surface, very fossiliferous, with *Schizophoria laudoni, Independatrypa randalia, Athyris vittata, Pseudoatrypa minor*, gastropods, bivalves, solitary tetracorals, and echinoderm ossicles.

2 0.54-2.54 SKELETAL WACKE-PACKSTONE: two massive beds, separated by shale parting 135 cm above base of unit, very fossiliferous, with abundant *Orthospirifer euruteines, Strophodonta (S.) randalia, S. (S.) parva, Tylothyris subvaricosa, Athyris vittata, Cyrtina umbonata, Pseudoatrypa minor*, echinoderm plates.

3 2.54-4.17 SKELETAL PACKSTONE: a single massive bed (=*Athyris vittata* beds of Udden), very fossiliferous, with very abundant *Athyris vittata, Cyrtina umbonata, Pseudoatrypa minor, Eosyringothyris aspera, Orthospirifer euruteines, Strophodonta (S.) randalia, S. (S.) parva*, and echinoderm debris. Megafossil Samples: BQ91-1F from lower 50 cm, BQ91-2F from upper 100 cm of Unit 3.

4 4.17-4.43 SKELETAL WACKESTONE & SHALE: consists of a basal 5-10 cm shale with atrypid brachiopods and echinoderm debris; overlain by a single bed (15-20 cm) of skeletal wackestone, with abundant *Athyris vittata*, and *Pseudoatrypa* sp. and echinoderm debris. Conodont Samples: BQ91/2-1'C from lower 10 cm shale bed, BQ91-1C from lower 20 cm of skeletal wackestone bed.

5 4.43-4.79 SKELETAL WACKESTONE: same as wackestone of Unit 4.

6 4.79-5.82 SKELETAL WACKESTONE-PACKSTONE: fossils common to abundant with *Athyris vittata, Strophodonta (S.) randalia*, large *Independatrypa randalia*, fish debris, fenestrate bryozoans, bivalves, echinoderm material, with large dolomite spar filled vugs in upper 30 cm. Conodont Samples: BQ91-2C taken from lower 20 cm, BQ91-3C taken from upper 20 cm of Unit 6.

7 5.82-6.02 SKELETAL PACK-WACKESTONE: well cemented, pyrite-encrusted, with well-developed hardground on irregular

upper surface of unit (up to 5 cm of relief), with *Independatrypa randalia*, *Strophodonta parva*, *Tylothyris subvaricosa*, and echinoderm debris. Conodont Sample: BQ91-3C taken from lower 10 cm of Unit 7.

LITHOGRAPH CITY FM.
ANDALUSIA MB.

8 6.02-6.58 SHALE & NODULAR WACKESTONE: very fossiliferous medium gray calcareous shale, with large skeletal wackestone nodules, compacted shell lag in upper 5 cm visible on lower surfaces of up-turned blocks of overlying unit in ramp fill. Contains extremely abundant *Strophodonta (S.) iowensis*, with *Eosyringothyris occidentalis*, *Allanella annae*, *Floweria callawayensis*, *Schizophoria lata*, *Independatrypa scutiformis*, bivalves, gastropods, solitary tetracorals, and echinoderm debris. Conodont Samples: BQ91/2-Unit 8A from lower 20 cm, BQ91/2-Unit 8B from 20-40 cm, BQ91/2-Unit 8C from upper 16 cm, BQ91-Unit 8 from compacted shell lag in upper 5 cm of Unit 8. Megafossil Samples: BQ91-Unit 8 consists of isolated specimens collected from entire unit, BQ91-Unit 8 Slabs are compacted shell lags from the upper 5 cm of unit.

9 6.58-7.41 SKELETAL WACKESTONE: very silty-argillaceous, with whole-shell uncompacted brachiopods, with abundant *Schizophoria lata* and *Independatrypa scutiformis*, with *Strophodonta(S.) iowensis*, *Allanella annae*, *Orthospirifer capax*, *Cyrtina* sp. A., and *Tecnocyrtina* sp. indet. Conodont Sample: BQ91-4C from lower 20 cm of Unit 9. Megafossil Sample: BQ91-Unit 9 from entire unit.

10 7.41-9.50 SKELETAL WACKE-PACKSTONE: dolomitic skeletal wacke-packstone, occurs as three thick-massive beds separated by shale partings. The lower bed is 40 cm thick, middle bed is 110 cm thick, upper bed is 59 cm thick, all are fossiliferous, with *Independatrypa scutiformis*, *Strophodonta (S.) iowensis*, *Cyrtina*? sp., *Allanella annae*, *Orthospirifer capax*, *Schizophoria lata*, solitary tetracorals, and echinoderm debris. Conodont Samples: BQ91-5C from lower 20 cm, BQ91-6C from 40-60 cm, BQ91-7C from upper 20 cm of Unit 10.

11 9.50-9.85 SKELETAL WACKE-PACKSTONE: 2 cm shale parting at base of unit, dolomitic, brachiopod (*Independatrypa*, *Schizophoria*, and *Strophodonta*) and echinoderm debris is common in lower 20 cm, with isolated and packed solitary tetracorals, and large branching ramose bryozoan, and large *Strophodonta* n. sp. in laminated dark-gray brown skeletal calcisiltite in upper 15 cm. Megafossil Sample: BQ91-Units 11-13 (Biostrome Interval Sample).

12 9.85-10.05 SKELETAL WACKESTONE-PACKSTONE: similar to Unit 11, only isolated solitary tetracorals present in lower carbonate bed, forming dense packed thicket, with bryozoans in laminated calcisiltite in upper 5-8 cm. Megafossil Sample: BQ91-Units 11-13 (Biostrome Interval Sample).

13 10.05-10.20 SKELETAL WACKE-PACKSTONE: similar to units 11 and 12 only thinner, with 2-3 species of nautiloids, and thin laminar stromatoporoids. Conodont Sample: BQ91-8C from entire 15 cm of Unit 13. Megafossil Sample: BQ91-Units 11-13 (Biostrome Interval Sample).

14 10.20-10.65 DOLO-SKELETAL WACKE-PACKSTONE: occurs at two thick beds, lower bed (37 cm) with prominent skeletal concentration in the lower 15 cm consisting of large *Strophodonta (S.)* n. sp., overlain by numerous solitary tetracorals; upper bed (30 cm) of skeletal wackestone with echinoderm debris and large *Strophodonta* n. sp.

15 10.65-12.15 DOLO-SKELETAL WACKE-MUDSTONE: occurs as three thick beds, lower bed (50 cm) with large scattered solitary tetracorals in lower 20 cm, with *Independatrypa scutiformis*, *Strophodonta (S.)* n. sp., *Allanella allani*; middle bed (50 cm) moldic echinoderms and *Strophodonta* with large open and saddle dolomite-lined secondary solution vugs; upper bed (50 cm) dolomite with moldic fossils (same as below), with large open and dolomite-lined solution vugs. Conodont Sample: BQ91-9C taken from lower 20 cm of Unit 15.

16 12.15-13.25 DOLO-SKELETAL MUDSTONE: occurs as four beds, lower thick bed (55-60 cm) with moldic *Strophodonta*, n. sp. large bellerophontid gastropods, and large open secondary solution vugs; overlain by three thin beds (10-15 cm) with poorly preserved moldic echinoderm and brachiopods. Conodont Sample: BQ91-10C taken from lower 15 cm, and BQ91-11C taken from 80-95 cm above the base of Unit 16.

BUFFALO QUARRY 1991-2 (BQ91/2)

LOCATION: located in the E 1/2, NE, NW, NE, Section 23, 77N, 2E, Scott County, Iowa. Exposure located on old bench immediately below old quarry road immediately above new cross-quarry ramp, north side of Davenport Cement Company Quarry, 150 m east of BQ91. Section consists of upper half section measured at BQ91, starting in upper part of BQ90-Unit 11 (consisting of BQ91 units 11-15).
MEASURED: 6/91 by Jed Day, with Steven Travers.

UNIT INTERVAL UNIT DESCRIPTION

LITHOGRAPH CITY FM.
ANDALUSIA MB.

11 0.00-0.27 SKELETAL WACKE-PACKSTONE: consists of two distinct intervals, the lower interval (20 cm) consists of a single bed of dolomitic

skeletal wacke-packstone; the upper interval (7 cm) consists of laminated dark gray argillaceous skeletal calcisiltite with large solitary tetracorals; contains gastropods, nautiloids, brachiopods including *Strophodonta* (*S.*) n. sp., *Schizophoria lata*, *Allanella allani*, and solitary tetracorals, corals particularly abundant in upper 7 cm interval. Megafossil Sample: BQ91/2 Unit 11.

12 0.27-0.41 SKELETAL WACKE-PACKSTONE: consists of two beds, lower bed (10 cm) of dolomitic skeletal wackestone; upper bed (5-8 cm) consists of dk. gray laminated calcisiltite with abundant large solitary tetracorals, branching ramose bryozoans, encrusting auloporid tabulate corals on tetracorals, and *Strophodonta*(*S.*) n. sp. and *Cyrtina* n.sp. Megafossil Sample: BQ91/2-Unit 12 from entire unit.

13 0.41-0.56 SKELETAL WACKE-PACKESTONE: similar to unit 13, with 2-3 species of undescribed nautiloids, with *Athyrisvittata* and *Strophodonta* (*S.*) n. sp. Megafossil Sample: BQ91/2-Unit 13 from entire unit.

14A 0.56-0.86 DOLO-SKELETAL WACKE-PACKSTONE: single thick bed of dolomitic skeletal wacke-packstone, with abundant *Strophodonta* (*S.*) n. sp. and echinoderm debris in lower 5-10 cm and above, with scattered solitary tetracorals in lower half, also with gastropods, *Allanella allani*, *Schizophoria lata*, *Cyrtina* n. sp.. Megafossil Sample: BQ91/2-Unit 14a.

14B 0.86-1.11 DOLO-SKELETAL WACKESTONE: single thick bed of dolomitic skeletal wackestone with scattered solitary tetracorals, *Strophodonta* (*S.*) n. sp., *Allanella allani*, *Schizophoria lata*, *Cranaena* n. sp., and the bivalve *Paracyclus* sp. Megafossil Sample: BQ91/2-Unit 14b.

14C 1.11-1.29 DOLO-SKELETAL WACKESTONE: single bed of dolomitic skeletal wackestone, with echinoderm debris and the brachiopods *Strophodonta* (*S.*) n. sp. and *Allanella allani*. Conodont Sample: BQ91/2-8'C from entire Unit 14c.

15A 1.29-1.60 DOLO-SKELETAL WACKE-MUDSTONE: dolomitic skeletal wacke-mudstone with small-med. scattered solitary tetracorals, echinoderm debris, large *Strophodonta* n. sp. and small *Athyris vittata*. Megafossil Sample: BQ91/2-Unit 15a.

15B 1.60-1.73 DOLO-SKELETAL MUD-FRAMESTONE: dolomitic skeletal mudstone, framestone where laminar actinostromid and branching amphiporid stromatoporoids form intergrown framework, contains brachiopods including *Strophodonta* n. sp., *Cranaena* n. sp., *Athyris vittata*, and *Lorangerella* sp. Megafossil Sample: BQ91/2-Unit 15b.

15C 1.73-1.93 DOLO-SKELETAL MUDSTONE: dolomitic skeletal mudstone with scattered echinoderm debris and *Strophodonta* n. sp., with large open and saddle dolomite-lined secondary solution vugs. Conodont Sample: BQ91/2-9'C from entire 20 cm of Unit 15C.

15D 1.93-2.33 DOLO-SKELETAL MUDSTONE: dolomitic skeletal mudstone with scattered echinoderm debris and *Strophodonta* n. sp., with open and dolomite-lined secondary solution vugs. Conodont Sample: BQ91/2-9"C from upper 20 cm of Unit 15D.

FOSSIL LOCALITY 9/91-A

LOCATION: Outcrop and quarry exposures of the Lower channel-fill facies of the State Member of the Lithograph City Formation, located on the west shore of Coralville Lake, south of Mehaffey Bridge in the SE, SE, SW, Section 5, T80N, R6W, Johnson County, Iowa.
VISITED: September 21, 1991 by canoe, Jed Day with Brian Witzke.

FOSSIL LOCALITY 9/91-B

LOCATION: Outcrop and quarry exposures of the Lower and Upper channel-fill facies of the State Member of the Lithograph City Formation, located on the west shore of Coralville Lake, south of Mehaffey Bridge in the SE, NW, NW, Section 8, T80N, R6W, Johnson County, Iowa.
VISITED: September 21, 1991 by canoe, Jed Day with Brian Witzke.

FOSSIL LOCALITY 9/91-C

LOCATION: Outcrops of the north margin skeletal mudstones and wackestones of the State Member, Lithograph City Formation, resting directly on the *Idiostroma* beds of the Cou Falls Member of the Coralville Formation, located on the west shore of Coralville Lake, south of Mehaffey Bridge in the SE, SW, NW, NE Section 8, T80N, R6W, Johnson County, Iowa.
VISITED: September 21, 1991 by canoe, Jed Day with Brian Witzke.

CONODONT FAUNAS OF THE LITHOGRAPH CITY FORMATION (CEDAR VALLEY GROUP, UPPER GIVETIAN-LOWER FRASNIAN) IN NORTH-CENTRAL AND EASTERN IOWA

by

James Kralick
Department of Geology
University of Iowa
Iowa City, Iowa 52242

INTRODUCTION

Recent revision of the stratigraphic nomenclature of the late Middle to early Upper Devonian rocks of north-central and eastern Iowa makes a brief review of current Lithograph City Formation terminology necessary. The Lithograph City is the third of four Cedar Valley Group formations, each of which constitutes a discrete transgressive-regressive sea level cycle (T-R cycle IIb, Johnson et al., 1985; Iowa T-R cycle 5, Witzke et al., 1988). Limestone and dolomite are the dominant lithologies of the Lithograph City in north-central Iowa where the formation is subdivided into two primary units: the basal Osage Springs Member, consisting of barren to fossiliferous dolomites to skeletal calcilutites/ calcarenites; and the Idlewild Member, which consists primarily of laminated to lithographic limestones and dolomites (the dolomitic and silty Thunder Woman Shale Member intervenes locally at the Osage Springs/ Idlewild contact southeastward; see Floyd-Mitchell cores #4 and #3, Fig. 1). In east-central Iowa the Lithograph City is as yet undifferentiated (Garrison Quarry composite section, Fig. 1; STOP 1). In Johnson County (eastern Iowa) a distinct facies change introduces cross-bedded skeletal calcarenites of the State Quarry Member (Indian Cave and Vanourny Quarry sections, Fig. 1) and, farther southeast another facies is represented by the argillaceous dolomites of the Andalusia Member (Day, this guidebook, fig. 3). The overall lithostratigraphic and biostratigraphic framework for these units is documented in Witzke et al. (1988) and a comprehensive review is offered by Bunker and Witzke (this guidebook).

BIOSTRATIGRAPHY

Conodonts of the Lithograph City Formation are representative of the *insita* biofacies, which in Iowa ranges from the *norrisi* Zone of the upper Givetian as high as Montagne Noire Zone 3 of the lower Frasnian. The reported association of *Pandorinellina insita* and *Skeletognathus norrisi* in the State Quarry Member (Watson, 1974; Klapper & Johnson, 1990) suggests the oldest part of the *insita* Fauna of Iowa, but is based on a single recovered specimen of *S. norrisi* (Watson, 1974). *Pandorinellina insita* also occurs in the uppermost Andalusia Member where it is associated with *Mesotaxis asymmetrica*, *Ancyrodella africana*, *A. alata*, and *A. rugosa* indicating a correlation with Montagne Noire Zone 3 (Day, 1990, this guidebook; Klapper, 1988).

In the Floyd-Mitchell cores (Fig. 1) and at Garrison Quarry (Fig. 1; STOP 1) the faunas of the lower Lithograph City (Osage Springs Member and equivalents) are sparse and often poorly preserved, consisting solely of *Pandorinellina insita.* The faunas of the upper Lithograph City (Idlewild Member and equivalents) at these localities typically have more conodonts, better preservation, and are characterized by combinations of *P. insita*, which predominates, indeterminate species of *Polygnathus*, and a Pa element of an undescribed new genus and species [= form illustrated by Uyeno (1974, Pl. 5, fig. 5 only, the sole illustration of this taxon currently known from the literature)]. The State Quarry Member conodont faunas show evidence of reworking (minor color alteration and abrasion, as is typical in the lower part of the unit) and are similar to the older upper *subterminus* Fauna of underlying rocks. These faunas contain *Icriodus subterminus,* which predominates, and the same indeterminate *Polygnathus* species as found at the other localities. *Mehlina gradata* also occurs in the basal State Quarry samples. Although the occurrence

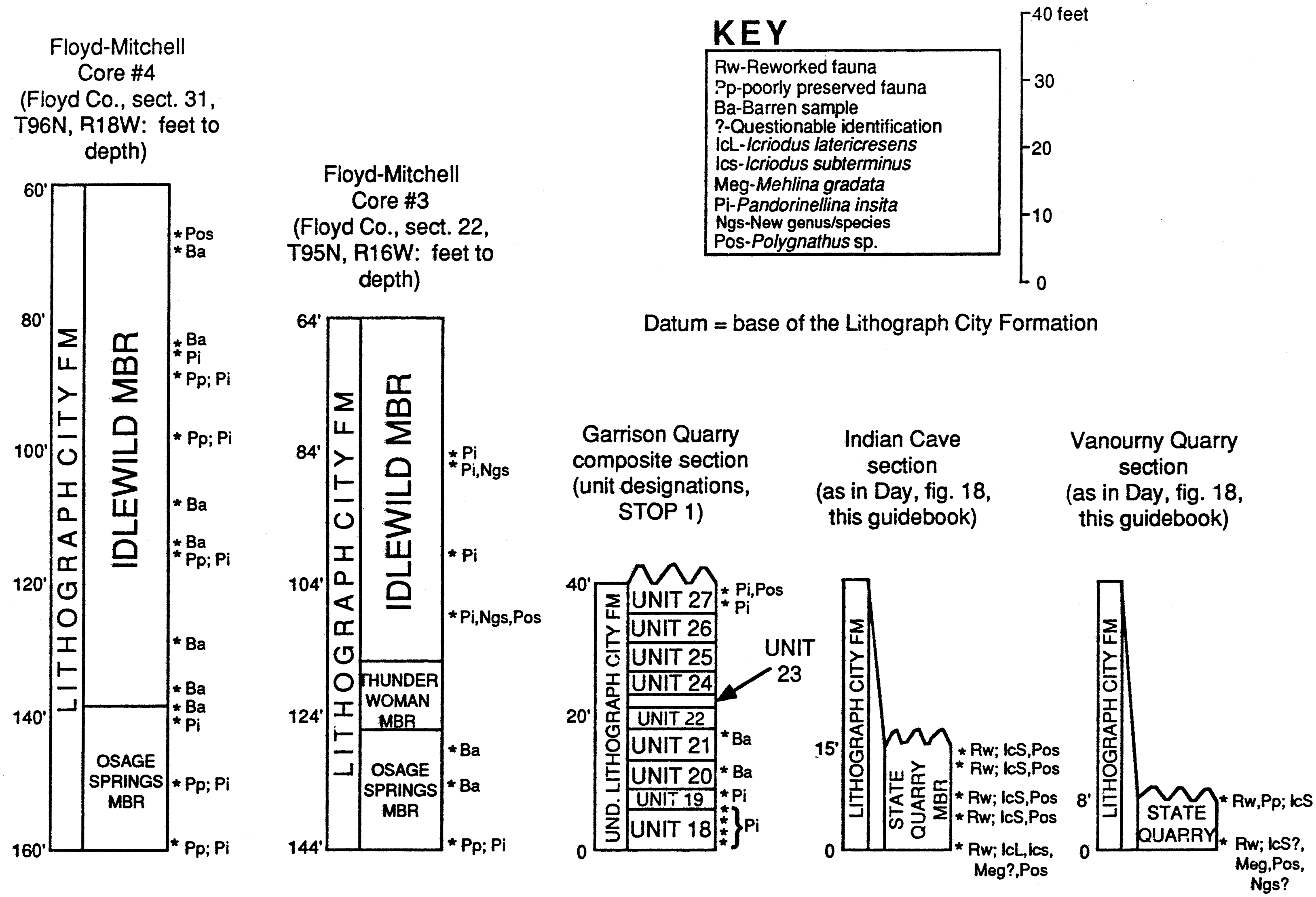

Figure 1. Representative graphic sections from core and outcrop data of the Lithograph City Formation in north-central and eastern Iowa.

of *P. insita* in the State Quarry is well documented (Watson, 1974; Klapper & Johnson in Johnson, 1990; Bunker, 1991, from unpublished collections) specimens of *P. insita* are conspicuously absent from all State Quarry units sampled in this study, further supporting the conclusion that faunas from low in the unit are primarily the result of reworking from underlying strata. Much of the Andalusia Member is characterized by faunas including *P. insita, I. subterminus, M. gradata*, and *Polygnathus angustidiscus*, as well as several poorly understood *Polygnathus* species such as *P. sp. cf. P. dubius* and *P. sp. cf. P. webbi.* As mentioned previously, *Pandorinellina insita* occurs with *Mesotaxis asymmetrica, Ancyrodella alata, A. rugosa*, and *A. africana* in the upper Andalusia Member (Day, this guidebook, fig. 10).

The presence of a new taxon in the Iowa Devonian sequence was alluded to by Bunker et al. (1986) and is recognized as a possible homeomorph of *Alternognathus regularis* Ziegler and Sandberg, 1984 (G. Klapper, 1991, pers. comm.). It has a well developed platform with distinct rows of marginal nodes parallel to the blade. Platform extension may be almost as far as the posterior tip. This form was reported by Uyeno (1974) from the lower Frasnian Moberly Member of the Waterways Formation in northeastern Alberta, Canada. Recognition of this new genus and species has potential biostratigraphic importance in that it may help to better constrain the questionable Middle-Upper Devonian boundary in Iowa. However, further systematic study and description of this new form and its occurrence should be deferred to a more appropriate forum. Witzke et al. (1988) correlated the Lithograph City with the "Micritic limestone beds" (Souris River Formation, Point Wilkins Member) of the Manitoba sequence (Norris et al., 1982) based on the co-occurrence of *P. insita* and *S. norrisi.*

Identification of the *Polygnathus* species found in these faunas is hindered by the undiagnostic nature of the platform elements. The upper platform surface is typically ridged to smooth and the platform margin often appears crenulated. The basal pit is large and ellipsoidal. The posterior tip is usually pointed and may be deflected slightly laterally. The species *Polygnathus* sp. *cf. P. pennatus*, *P.* sp. *cf. P. dubius*, and *P. webbi* occur in similar faunas from Alberta (Norris and Uyeno, 1983) and it is possible that the indeterminate *Polygnathus* species found in Iowa are related to these forms.

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DISTRIBUTION AND BIOSTRATIGRAPHIC SIGNIFICANCE OF MIOSPORES IN THE MIDDLE - UPPER DEVONIAN CEDAR VALLEY GROUP OF IOWA

by

Curtis R. Klug
Department of Geology
University of Iowa
Iowa City, Iowa 52242

INTRODUCTION

The purpose of the present paper is to document the ranges and biostratigraphic significance of select Devonian miospores at the River Products Conklin Quarry, and part of the Garrison Quarry (Fig. 1). The strata examined in these two quarries belong to the Little Cedar, Coralville, and Lithograph City formations of the Cedar Valley Group (following Witzke, Bunker, and Rogers, 1989). The former locality (STOP 4 of this field trip) served as the reference section for the Little Cedar and Coralville formations in a more comprehensive examination of miospore distributions in the Cedar Valley Group of Iowa (Klug, 1990). The latter locality (STOP 1 of this trip) provided miospores from three samples in the Lithograph City Formation. Only named miospore taxa are considered herein. These, however, represent only a small part of the Iowa Devonian miospore flora, the bulk of which appears to be undescribed. The remainder of the flora, along with systematic descriptions, is to be published at a later date.

Two-kilogram samples were systematically collected through the section exposed at the River Products Conklin Quarry, at a spacing of approximately 1 meter, and processed simultaneously for conodonts and miospores. Only three samples were processed from the quarry at Garrison. These include a paper coal and the shales under- and overlying it (see Klug and Schabilion, this guidebook). Approximately 500 grams of the shale underlying the coal were processed for miospores, but produced only about a dozen specimens. Similarly, only a few spores have been isolated from the paper coal itself. In contrast, only two grams were processed from the shale overlying the paper coal. Nevertheless, this sample produced more miospores than any other examined (Klug, 1990) from the Cedar Valley Group of Iowa. While conodonts were not obtained from the Garrison Quarry samples in the present study, they are described by Kralick (this guidebook).

Miospores occur throughout the Middle to Upper Devonian strata of the Cedar Valley Group of Iowa. The section is dominated by limestones and dolostones, but shales may be important locally. Interpreted depositional environments generally range from open-marine subtidal to supratidal mudflat, although fluvial deposits may also occur.

Miospores are defined as spores less than 200 μm in diameter regardless of biological function. The term was proposed by Guennel (1952) for spores in the fossil record, where it is impossible to distinguish between isospores and microspores. Isospores are those "small" spores that, upon germination, produce a gametophyte that is functionally either male, female, or both. Microspores are similar in size to isospores, but produce gametophytes that develop only male reproductive structures. Yet another category of spores, megaspores, are those that are over 200 μm in diameter and produce gametophytes that develop only female reproductive structures. Megaspores are relatively rare in the Iowa Devonian strata, but may be important locally. Only miospores are considered in this paper as they tend to be more abundant than megaspores, and appear to have greater biostratigraphic utility.

The majority of miospores recovered from the Devonian strata of Iowa are characterized by a trilete mark, that is, a triradiate aperture through which the spore contents emerge upon germination. The resistant walls of the miospores and the presence of trilete marks are thought to have been developed as adaptive responses to the effects of desiccation in a subaerial environment. Consequently, the possession of these features is generally considered (e.g. Gray and Boucot, 1977) to indicate derivation of the miospores from terrestrial plants.

Conodonts are widely recognized for their biostratigraphic utility, and an extensive zonation scheme

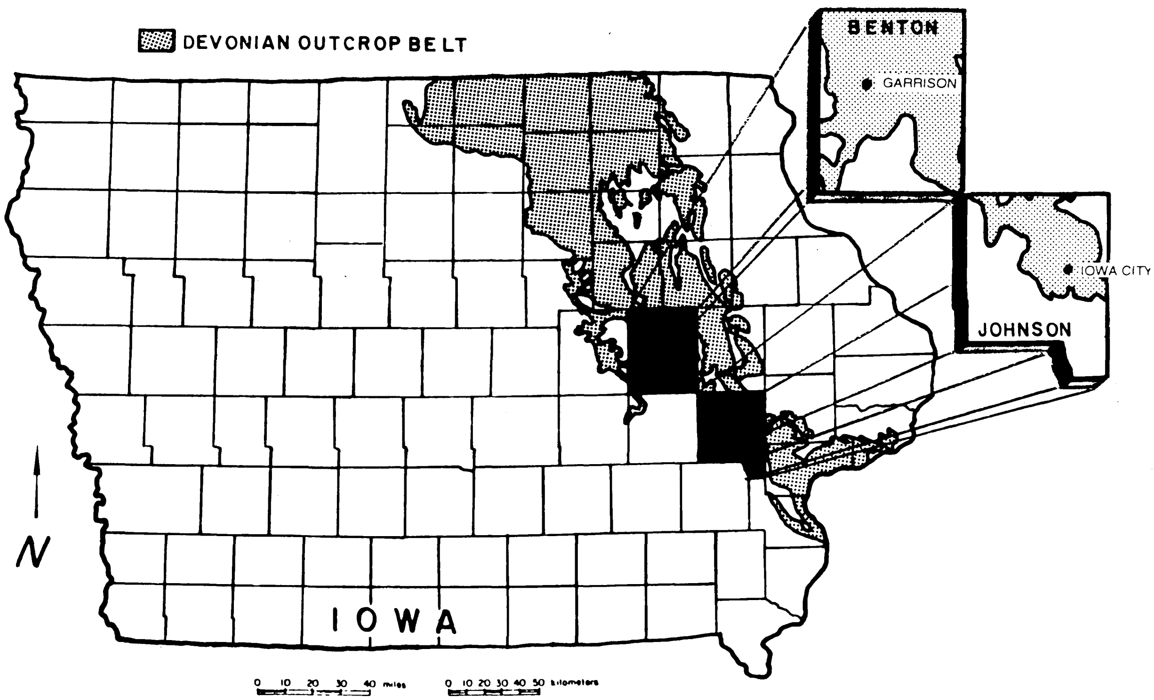

Figure 1. Location map of Iowa showing the Devonian outcrop belt, and the locations of the River Products Conklin Quarry at Iowa City and the quarry at Garrison.

based on conodonts has been established for marine strata of Devonian age (see e.g. Klapper and Ziegler, 1979). The biostratigraphic utility of Devonian miospores, however, has not been explored as extensively as has that of the conodonts. This is due, in part, to the fact that there has been a tendency, understandably, for miospore investigators to concentrate on strata of continental environments. The typically discontinuous nature of continental deposits and the general lack of other remains of recognized biostratigraphic utility has, to some extent, hampered the development of miospore biostratigraphy. Furthermore, Devonian miospore palynology is a relatively young science. Prior to the pioneering work of Naumova (1953), relatively little information on Devonian miospore floras was available. The Devonian was a time of considerable expansion of plants into the terrestrial environment, and was accompanied by rapid evolution of the floras. Consequently, Devonian miospore floras, not uncommonly, are very diverse. Much of the early work was primarily descriptive in nature and, even now, largely undescribed miospore floras are frequently encountered (e.g. Balme, 1988). As a result, generic and specific concepts of Devonian miospores, as well as their stratigraphic ranges, have been less than firmly established. The Iowa Devonian miospore flora is one of these very diverse floras, and may consist of as many as 300 species, most of which appear to be undescribed.

Despite the problems with Devonian miospore taxonomy and distribution, considerable progress has been made in the exploration of the biostratigraphic utility of miospores. McGregor (1979) published a range chart of 74 miospores that he considered biostratigraphically useful in North America. He concluded, however, that it was premature to establish a refined zonation based on the miospores until more reliably dated, continuous sections have been studied. Biostratigraphic zonation schemes have been proposed in a number of publications (Lianda, 1981; Arkhangelskaya, 1985; see also McGregor, 1981, fig. 2), but these have failed to achieve widespread acceptance. More recently, Richardson and McGregor (1986) established a miospore zonation for the Silurian and Devonian of the Old Red Sandstone continent and adjacent regions. They recognized 19 assemblage biozones and calibrated these with established graptolite, ammonoid, tentaculitid, and conodont zones. Similarly, Loboziak and Streel (1988) erected a miospore zonation for the Boulonnais of northern France. They recognized six zones ranging from the Givetian to the early Famennian. They also compared their spore zones with available conodont data for the region. While these zonation schemes have not been around long enough to have been critically evaluated, they appear to have some biostratigraphic utility for the Devonian of Iowa, and the stratigraphic ranges of the Iowa miospores will be discussed with respect to these latter two zonal sequences.

While miospores are generally thought to have been terrestrial in origin, their small size allows them to be readily transported, by air or water, to a variety of depositional settings, including those of the marine environment. As such, they are potentially excellent tools for biostratigraphic correlations between the marine and continental realms. In the Devonian of Iowa, miospores are frequently recovered from marine strata with diverse invertebrate faunas, including biostratigraphically important forms such as conodonts. In addition to the comparison of the Iowa Devonian miospores with the zonation schemes of Richardson & McGregor (1986) and Loboziak & Streel (1988), the potential biostratigraphic utility of the miospores in the Devonian of Iowa is also evaluated with respect to the ranges and zonation of conodont faunas recovered from the same section.

PREVIOUS WORK

Relatively few studies have been concerned with Devonian miospores of Iowa. Dow (1960) noted the presence of spores in thin coal seams in the "Cedar Valley Formation" of Johnson County, Iowa, but did not describe the flora. Norton (1967), in an abstract, reported the presence of 87 species in 32 genera from the "Solan (sic) Member of the Cedar Valley Formation". Sanders (1968) examined the palynological content of the above-mentioned coals in greater detail, and reported the presence of seventeen species in eleven genera, including three new species. He also compared the Iowa coal miospore flora with mid-Givetian floras of Vestspitsbergen, Scotland, and Australia, and with a Frasnian assemblage from Canada. Urban (1968, 1969), Bradshaw (1982), Playford, Wicander, and Wood (1983) each reported on a single or a few species from the Devonian of Iowa. Wicander and Playford (1985) also reported on the occurrence of a moderately diverse miospore flora, as well as acritarchs, from the Upper Devonian Lime Creek Formation of Iowa. Storrs (1987), in a report on an icthyofauna from the subsurface Devonian of northwestern Iowa, included photographs of several miospores -recovered from the strata bearing the fish fossils. To date, however, no detailed biostratigraphic examination has been made of the Devonian miospores of Iowa.

RANGES OF MIOSPORES AND CONODONTS AT THE RIVER PRODUCTS CONKLIN QUARRY AND THE QUARRY AT GARRISON

In general, in the Iowa Devonian, the presumably terrestrial miospores are most abundant and diverse in the strata of the Little Cedar Formation. It is of interest that these strata are interpreted to represent the most offshore, open marine conditions in the Cedar Valley Group. These strata are characterized by abundant and diverse invertebrate faunas, including conodonts. In contrast, the overlying Coralville and Lithograph City formations are, for the most part, interpreted to represent deposition under nearer shore, shallow subtidal to supratidal settings. Intuitively, one might expect the miospores to be most abundant in these upper, presumably nearer shore deposits. Such, however, is generally not the case. In fact, these strata typically, but not invariably, produce relatively low abundance, low diversity miospores floras. Syn- or postdepositional removal of the spores as a result of oxidation is considered unlikely as these strata commonly contain abundant alete spores (those lacking an aperture) of presumed algal origin. The walls of these algal spores are composed of the material sporopollenin, as are the walls of the miospores, but tend to be somewhat thinner than the walls of the miospores. It seems unlikely that the miospores would have been removed while the algal spores remained intact. Furthermore, the miospores found in these strata are often well preserved, and show no incipient degradation, as might be expected if they had been subjected to prolonged oxidizing conditions. Also, some of these strata contain brassy, unoxidized pyrite. If extended postdepositional oxidation were responsible for the removal of the spores, it would be expected that the pyrite would be altered to limonite or hematite. This is not to say that postdepositional oxidation was never responsible for the elimination of miospores from the strata. In fact, some beds are characterized by abundant iron oxides, presumably at the expense of the iron sulfides, and it is possible that, in these cases, oxidation did obliterate the spores. Generally, however, this does not appear to have been the case. An alternative explanation, and the one favored herein for most of the strata, is that the bulk of the spores were derived from "upland habitats", whereas relatively few were derived from plants living in the paralic environments. While most of the spores were presumably initially released into the air, transportation to the depositional basin was more likely through channelized runoff. The spores, carried by streams, presumably bypassed the paralic environments and, once reaching the sea, were probably transported offshore by currents. The results are the high abundance, high diversity miospore floras, representing a variety of terrestrial habitats, in direct association with open marine faunas. Whether or not the above scenario is correct, the co-occurrence of the miospores and the marine faunas should greatly facilitate correlations between the marine and terrestrial environments.

Little Cedar Formation

The oldest formation of the Cedar Valley Group is the Little Cedar Formation. At the River Products Conklin Quarry, this formation is subdivided into two members, the Solon and the overlying Rapid Members. Samples from the basal 2.9 meters of the Solon Member (RPQ-2 to RPQ-4) produced a conodont fauna including *Polygnathus ansatus, P. timorensis, P. linguiformis klapperi, P. linguiformis weddigei,* and *Ozarkodina semialternans* (Fig. 2). This association indicates assignment of these strata to the Middle *Polygnathus varcus* Subzone. A few spore taxa were recovered only from strata that produced conodonts of the Middle *varcus* Subzone (Fig. 3). These include *Grandispora* cf. *G. velata* and *Perotriletes* cf. *P. selectus*. Each of these, however, is represented by fewer than 5 specimens, and may not give an accurate idea of the distribution of these taxa in the Devonian of Iowa. For example, *G.* cf. *G. velata* has been recovered only from the lower part of the Solon Member of the Little Cedar Formation (RPQ-4). *G. velata* (= *Calyptosporites velatus* of Richardson and McGregor, 1986), with *Rhabdosporites langii*, serves to define the base of the early Eifelian *Calyptosporites velatus - Rhabdosporites langii* Assemblage Zone of Richardson and McGregor, 1986. Both of these species, however, have been reported to range as high as the Frasnian. *Perotriletes* cf. *P. selectus* has been reported from strata of Upper Eifelian to Givetian age. The conodonts and associated miospores from the lower part of the Solon Member at the River Product Conklin Quarry imply a mid-Givetian age for these strata.

Other miospore taxa that first occur, in Iowa, in association with conodonts of the Middle *varcus* Subzone include: *Ancyrospora langii, A. simplex, Archaeozonotriletes* cf. *A. variabilis* subsp. *variabilis, Geminospora lemurata, Laiphospora membrana, Lophozonotriletes* cf. *L. dentatus, Lophozonotriletes media, Rhabdosporites langii, Verrucosisporites scurrus.*

The above miospore association, prior to the first occurrence of *Cristatisporites triangulatus*, suggests assignment of the lowest 2.9 m of the Solon Member at the River Products Conklin Quarry to the *Geminospora lemurata - Cymbosporites magnificus* Assemblage Zone of Richardson and McGregor (1986). *Cymbosporites magnificus* has not been recognized in the Devonian of Iowa. *Geminospora lemurata*, on the other hand, is probably the most commonly encountered species. In fact, the miospore floras of the Cedar Valley Group are dominated by species of the genus *Geminospora*. *G. lemurata*, by itself, is of limited biostratigraphic value in the Iowa Devonian section, as this species ranges through the Cedar Valley Group and has also been reported by Wicander and Playford (1985) from the overlying Lime Creek Formation of Frasnian age.

Of particular interest in this miospore association is a form that appears to be identical to *Lophozonotriletes media*. This species, outside of Iowa, has only been reported from strata dated as Frasnian to Famennian age. The first occurrence of this species along with *Pustulatisporites rugulatus* has been used to define the base of the *bullatus - media* miospore zone established by Loboziak and Streel (1988) from the Boulonnais, France. The base of this zone, according to Loboziak and Streel, occurs within the Upper *Polygnathus* (= *Mesotaxis*) *asymmetricus* conodont zone of mid-Frasnian age. *L. media* was recovered from the lowest sample (RPQ-1) at the River Products Conklin Quarry. This sample was actually collected from the Davenport Member of the Pinicon Ridge Formation, which is part of the underlying Wapsipinicon Group. The Davenport Member, however, is highly brecciated in the quarry, and the matrix of this unit is largely composed of material leaked from the overlying Solon Member. Despite the evidence for stratigraphic leakage in this sample, it is extremely unlikely that the spores could have been derived from strata assigned to the Upper *asymmetricus* conodont zone, as this zone is considerably younger than the ages indicated for the strata by any of the conodont faunas recovered in the quarry. Furthermore, *L. media* has also been recovered from the Solon Member at a quarry at Vinton Iowa in association with conodonts of the Middle or Upper *varcus* Subzone, suggesting a mid-Givetian age. At that locality, there is no evidence of reworking or stratigraphic leak. The Iowa occurrences of *L. media* are believed to represent a significant extension of the known range for this species.

Samples from the upper 2.5 meters of the Solon Member (RPQ-5 to RPQ-7) produced conodont faunas including *Polygnathus* cf. *P. ansatus*, *Ozarkodina semialternans*, and *Icriodus latericrescens latericrescens*. This fauna suggests assignment of these strata to either the Middle or Upper *varcus* Subzones. The faunas, unfortunately, do not allow a more refined zonal assignment, but stratigraphic position suggests that this interval may represent the Upper *varcus* Subzone. Klapper in Ziegler, Klapper, and Johnson (1976) reported the conodont *Schmidtognathus wittekindti* from the uppermost .9 m at the nearby Solon Quarry, suggesting that the uppermost Solon may belong to the *Schmidtognathus hermanni* Zone.

The only miospore species that makes its first occurrence in the upper part of the Solon Member (RPQ-7) is *Grandispora naumovae* which ranges up to the top of the Rapid Member (RPQ-27). Outside of Iowa, this species has been reported from strata of early Eifelian to late Givetian age (McGregor, 1979). This species is one of the nominal species of the mid-Eifelian to early Givetian *Densosporites devonicus - Grandispora naumovae* Assemblage Zone of Richardson and McGregor (1986). This zone immediately precedes the *lemurata - magnificus* Assemblage Zone, and is not recognized in the Cedar Valley Group. The miospores so far recovered from both the lower and upper parts of the Solon Member suggest assignment of that unit to Richardson and McGregor's *lemurata - magnificus* Assemblage Zone.

The lower part of the Rapid Member of the Little Cedar Formation at the River Products Conklin Quarry (RPQ-8 and RPQ-9) produced abundant conodonts including: *Icriodus* cf. *I. brevis*, *I. difficilis*, *I. expansus*, *I. latericrescens latericrescens*, *Polygnathus varcus*, *P. xylus xylus*, and *Schmidtognathus wittekindti*. The first occurrence of the last-named species suggests assignment of this fauna to the *Schmidtognathus hermanni* Zone to as high as the Lower *Palmatolepis* (= *Klapperina*) *disparilis* Subzone (Klapper and Johnson in Johnson, 1990). The occurrence of *P. varcus* with *S. wittekindti*, however, does not agree with the ranges of the species given by Ziegler in Klapper and Ziegler (1979, text-figure 5) and suggests an upward extension of the range of *P. varcus*. Unless this is a considerable range extension of this species, the presence of *P. varcus* with *S. wittekindti* suggests assignment of the lowest 1.1 meters of the Rapid Member at the Conklin Quarry to the Lower *hermanni* Subzone.

In sample RPQ-10, *Schmidtognathus wittekindti* was recovered with *Icriodus difficilis* and *Polygnathus xylus xylus*, but no specimens of *P. varcus*. Conodont species first encountered in this sample were *Polygnathus ovatinodosus*, *Elsonella rhenana*, and a species of *Prioniodina*.

Samples RPQ-11 to RPQ-25 produced essentially the same conodont faunas with some modifications. Sample RPQ-12 produced a single broken platform element that appears similar to *Polygnathus webbi*. Sample RPQ-15 produced the last occurrence of *Schmidtognathus* and the last specimen of *Elsonella rhenana* was obtained from RPQ-16. Above RPQ-16, faunal diversity and abundance generally decreases with a few long-ranging species of *Icriodus* and *Polygnathus* making up the bulk of the faunas. Conodont faunas of samples RPQ-10 to RPQ-25 suggest assignment of the interval from 1.1 to 140.2 meters above the Solon-Rapid contact at the River Products Conklin Quarry to the *Schmidtognathus hermanni* Zone or possibly the Lower *disparilis* Subzone.

Miospores first encountered in this interval include: *Cristatisporites triangulatus* (= *Samarisporites triangulatus* of authors), *Geminospora* cf. *G. spinosa*, *Geminospora tuberculata*, and *Retusotriletes* cf. *R. triangulatus*. The first-mentioned species is of particular interest in that it has been used as one of the nominal species for miospores zones established by Richardson and McGregor (1986) and by Loboziak and Streel (1988).

The first occurrences of *Cristatisporites triangularis*, and *Contagisporites optivus* var. *optivus* Owens, 1971 define the base of the *Contagisporites optivus* var. *optivus - Cristatisporites triangulatus* Assemblage Zone of Richardson and McGregor (1986). According to Richardson and McGregor (1986), this zone is of late Givetian to early Frasnian age, and corresponds approximately to the conodont zonation ranging from the Upper *varcus* Subzone to the Lower *asymmetricus* Zone. As noted above, no conodonts diagnostic of the Upper *varcus* Subzone have been recovered from the Iowa Devonian and presence of this subzone is based primarily on stratigraphic position between strata with faunas of the Middle *varcus* Subzone and the *hermanni* Zone. It may be that the Upper *varcus* Subzone is not represented in the section at the River Products Conklin Quarry or, alternatively, that miospore floras of the *optivus triangulatus* Assemblage Zone occur slightly higher with respect to conodont zones in the Iowa section than it does elsewhere. It is also possible that examination of additional material from Iowa will turn

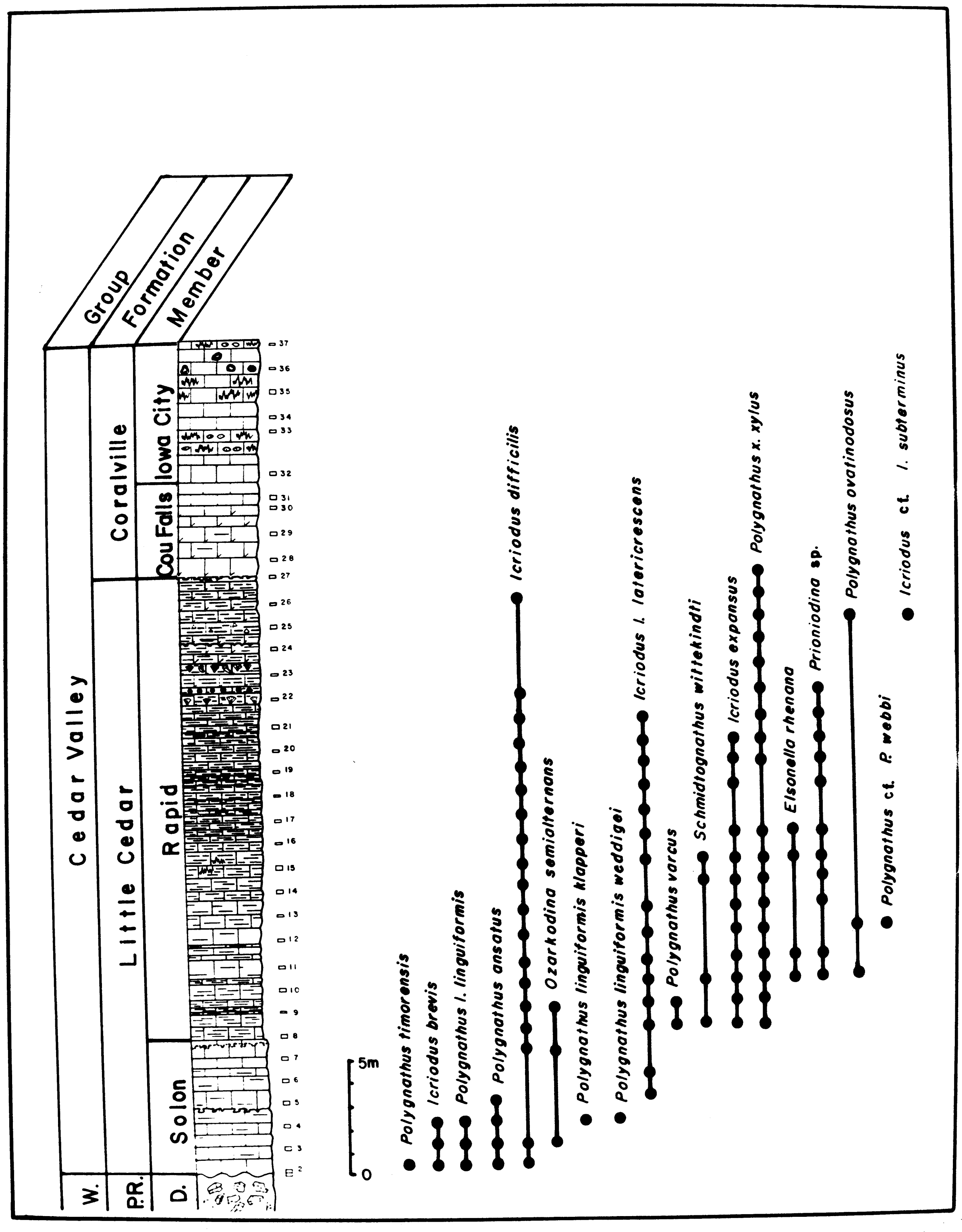

Figure 2. Ranges of conodonts in the section at the River Products Conklin Quarry.

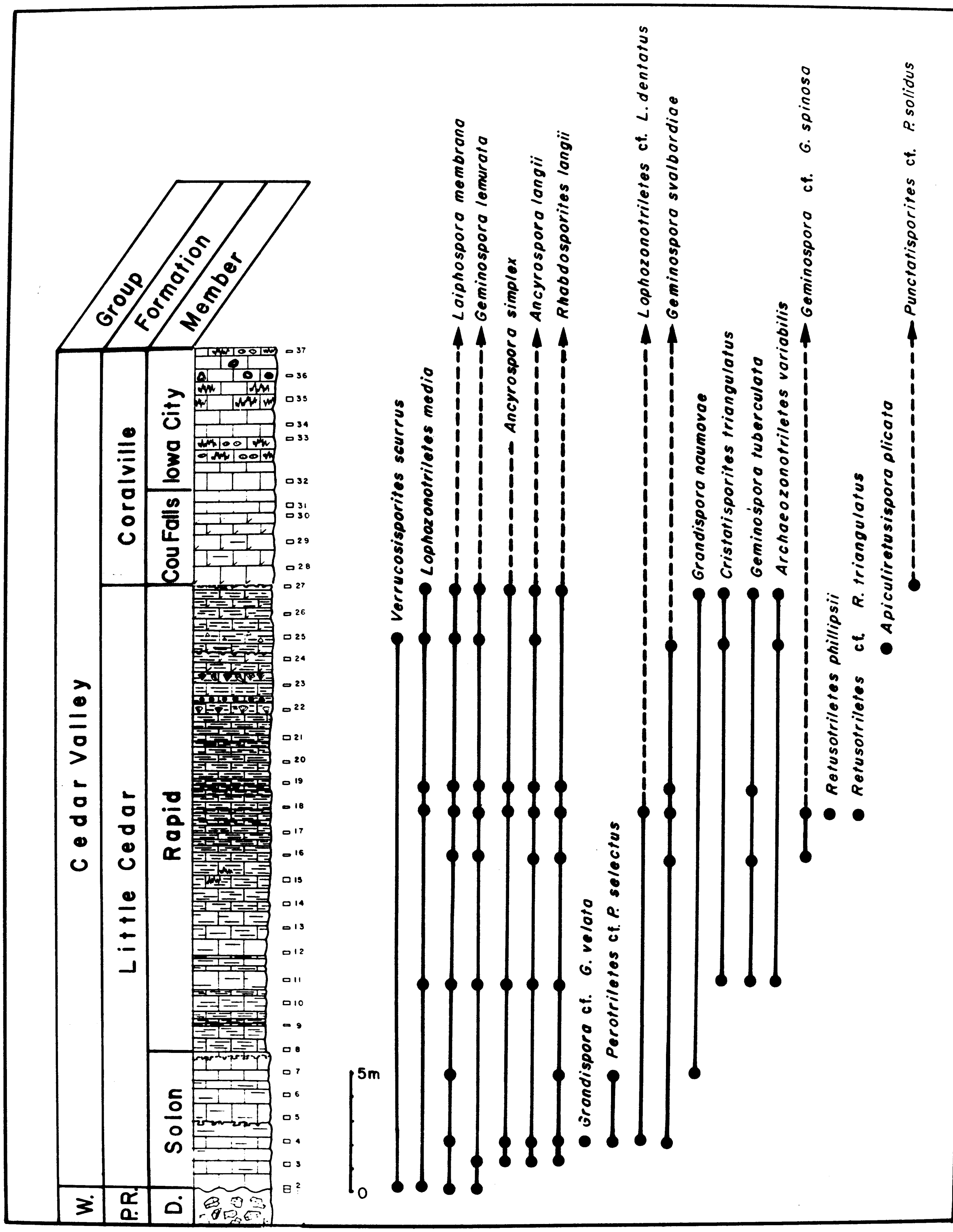

Figure 3. Ranges of miospores in the section at the River Products Conklin Quarry.

up specimens of *Cristatisporites triangulatus* in association with the presumed level of the Upper *varcus* Subzone.

Cristatisporites (= *Samarisporites*) *triangulatus* serves as one of the nominal species in two of the miospore zones proposed by Loboziak and Streel (1988) based on material from the Boulonnais, France. These are, the *Samarisporites triangulatus - Rhabdosporites langii* Zone and the overlying *Samarisporites triangulatus - Chelinospora concinna* Zone. According to Loboziak and Streel (1988), the *triangulatus - langii* miospore zone corresponds to the *Polygnathus xylus ensensis* conodont zone of Givetian age. This zone precedes the *varcus* Zone, and is not represented by the strata of the Cedar Valley Group.

The base of the *triangulatus - concinna* Zone is marked by the first occurrences of *Chelinospora concinna*, *Cirratriradites jekhowskyi*, and *Geminospora lemurata*. Only the last-mentioned of these has been recognized in the Devonian of Iowa. According to Loboziak and Streel (1988), the *triangulatus - concinna* Zone, in the Boulonnais, corresponds to the Middle *varcus* Subzone to the Lower *asymmetricus* Zone. *Cristatisporites triangulatus*, first occurs in the Boulonnais well below the first occurrence of *Geminospora lemurata*. In Iowa, *C. triangulatus*, as noted above, first occurs in the Rapid Member of the Little Cedar Formation above the first occurrence of *G. lemurata*. Based on conodont faunas, the Solon Member at the River Products Conklin Quarry should correspond to the *S. triangulatus - C. concinna* miospore zone. As indicated above, the assignment of these strata to this zone cannot be made on the basis of miospores. Furthermore, the discrepancies in the ranges of *C. triangulatus* and *G. lemurata*, as presented by Richardson and McGregor (1986), Loboziak and Streel (1988), and in the present study suggest that considerable refinement of the miospore zonations is needed. At this point, it appears that the Iowa Devonian miospore floras fit into the zonation scheme proposed by Richardson and McGregor (1986) better than that of Loboziak and Streel (1988).

Another problematic occurrence in the Cedar Valley Group of Iowa is a single specimen that appears identical to *Retusotriletes phillipsii* Clendening, Eames, and Wood, 1980. This specimen was recovered from sample RPQ-18 in the Rapid Member of the Little Cedar Formation. This species has been considered to be indicative of the Famennian (Clendening, Eames, and Wood, 1980). The Iowa specimen represents a considerable range extension for this species into strata of late Givetian age. There is no evidence from the remainder of the flora or fauna from this level, nor from any lithologic perspective, to suggest the reworking of younger material into this sample. Clearly it is very desirable to obtain additional specimens of this species to verify the occurrence.

Conodont faunas of the upper Rapid Member of the Little Cedar Formation and the Coralville Formation tend to be sparse and largely nondiagnostic. Specimens of *Icriodus* recovered from the upper Rapid (RPQ-25) appear close to, if not conspecific with *Icriodus subterminus*. The first occurrence of this species marks the base of the *I. subterminus* Fauna of Witzke, Bunker, and Klapper (1985). Some specimens of *Icriodus* from somewhat lower in the section (as low as RPQ-13) bear some similarities to, but are probably not conspecific with, *I. subterminus*. Faunas of the upper Rapid and Coralville (above RPQ-25) also include specimens of *Icriodus*, but no *I. subterminus*. There is, in the writer's opinion, some question as to the identity of this species. Specimens clearly assignable to *I. subterminus* do occur in the State Quarry and Andalusia Members of the Lithograph City Formation. Regardless of correct specific assignment, the *subterminus*-like *Icriodus* in the upper part of the Rapid Member appears to be of biostratigraphic value. The occurrence of this "species" below the first occurrence of *Polygnathus angustidiscus* and *Mehlina gradata* is referred to as the lower *I. subterminus* Fauna. This fauna is recognized in the upper part of the Rapid Member of the Little Cedar Formation and has been considered to be a probable Lower *disparilis* Subzone equivalent.

Most of the miospores previously mentioned also occur in association with the lower *subterminus* Fauna. *Apiculiretusispora plicata* and *Punctatisporites* cf. *P. solidus* first occur in the uppermost part of the Rapid Member at the River Products Conklin Quarry (RPQ-25 and RPQ-27, respectively). *A. plicata* has been reported to range from strata of Early Siegenian to Late Givetian age (McGregor, 1979). This species was also reported (as *Planisporites plicatus*) from the Iowa City Member of the Coralville Formation by Sanders (1968). *P.* cf. *P. solidus* ranges from the upper part of the Rapid Member of the Little Cedar Formation into the Mason City Member of the Shell Rock Formation. Outside of Iowa, *P. solidus*, or forms very similar to it, have been reported in strata ranging in age from ?upper Eifelian to Tournasian.

Several miospore species have their last occurrence in the Rapid Member of the Little Cedar Formation. These include: *Archaeozonotriletes variabilis*, *Geminospora svalbardiae*, *Grandispora naumovae*, *Lophozonotriletes* cf. *L. dentatus*, *Rhabdosporites langii*, and *Verrucosisporites scurrus*.

Coralville Formation

The Coralville Formation at the River Products Conklin Quarry is subdivided into the Cou Falls and Iowa City Members. At this locality, these units tend to be poorly productive of both conodonts and miospores. Only samples RPQ-30 and RPQ-31 (1.9 to 3.7 meters above the Little Cedar/Coralville contact) produced conodonts, and these were a few nondiagnostic specimens of *Icriodus*. Witzke, Bunker, and Rogers (1989) report the occurrence of *Icriodus subterminus* and *Mehlina gradata* from the Cou Falls Member, indicating assignment to the upper *Icriodus subterminus* fauna. They suggest that this fauna is a probable equivalent of the Upper *disparilis* Subzone. At the River Products Conklin Quarry, only a single miospore, referable to *Geminospora lemurata* has been recovered (RPQ-36) from the Iowa City Member of the Coralville Formation.

Despite the fact that the Coralville Formation is essentially barren at the River Products Conklin Quarry, elsewhere both abundant and diverse miospore floras have been recovered from this unit. For example, on the campus of the University of Iowa approximately 2 miles southeast of the River Products Conklin Quarry, an exposure of the Iowa City Member of the Coralville Formation includes a thin coal. This coal produced an abundant and diverse miospore flora (Sanders,1968; Klug, 1990). Miospores recovered from this coal extended the ranges of several species (e.g.*Ancyrospora langii*, *Apiculiretusispora plicata*, and *Geminospora tuberculata*) upward in the Iowa Devonian. Further examination of the miospore sample from the shale above the Garrison coal, after the figures were compiled for this paper, also showed the presence of *Ancyrospora simplex*, extending the range of this species in the Iowa Devonian as well.

Lithograph City Formation

Another localized occurrence, not unlike that of the coal in the Coralville Formation, is a paper coal and the associated shales exposed at the Garrison Quarry (STOP 1 of this field trip). While the coal and underlying shale have produced relatively few miospores, the overlying shale has produced the most prolific miospore flora examined to date by the author. This shale occurs within the Lithograph City Formation, which overlies the Coralville Formation. The palynomorph sample from this shale produced a miospore assemblage including: *Ancyrospora langii*, 1965; *Cristatisporites triangulatus*, *Geminospora lemurata*, and *Laiphospora membrana*. At the time of writing, only a preliminary examination of the palynomorphs of this shale had been made and the above-mentioned miospores by no means represent the complete miospore flora from this unit. The co-occurrence of *C. triangulatus* and *G. lemurata* suggest assignment of these strata to either the *optivus - triangulatus* or *ovalis - bulliferus* Assemblage Zones of Richardson and McGregor, 1986. Richardson and McGregor (1986, Figure 2) show that the first occurrence of *C. optivus* var. *optivus* is slightly higher than that of *C. triangulatus*. *C. optivus* var. *optivus*, *A. ovalis*, and *V. bulliferus* have not been noted at Garrison and suggest assignment to the former assemblage zone. Prior to this investigation, *Ancyrospora langii* has not been noted higher than the coal in the Iowa City Member of the Coralville Formation. This species, however, has been reported from strata as young as the Famennian (Loboziak and Streel, 1981). *Laiphospora membrana* ranges through the Cedar Valley Group and into the overlying Lime Creek Formation. The above miospore assemblage suggests a latest Givetian to earliest Frasnian age for these strata. This is in agreement with the conodont faunas recovered from strata encompassing the paper coal and adjacent strata (Kralik, pers. comm. 1991).

Miospores were also recovered from strata of the Shell Rock Formation of the Cedar Valley Group (Klug 1990). Discussion of these miospore floras, however, is considered beyond the scope of the present paper as there will be no opportunity to visit any exposures of the Shell Rock Formation on this trip.

SUMMARY AND CONCLUSIONS

The Devonian strata exposed at the River Products Conklin Quarry are assigned to the two formations, the Little Cedar and the overlying Coralville. The former is subdivided into the Solon and overlying Rapid Member. The Coralville Formation is subdivided into the Cou Falls and overlying Iowa City Members. Miospores and conodonts are abundant and diverse in both the Solon and Rapid Members of the Little Cedar Formation. The conodonts of the lower part of the Solon Member suggest assignment of these strata to the Middle *varcus* Subzone of the standard conodont zonation. While the conodonts from the upper part of the Solon Member may belong to either the Middle or Upper *varcus* Subzones, stratigraphic position suggests that this interval may be assigned to the latter. Miospores recovered from the Solon Member suggest assignment of this unit to the *lemurata - magnificus* Assemblage Zone of Richardson and McGregor (1986). Conodonts from all but the uppermost part of the Rapid Member indicate assignment of this interval to the *hermanni* conodont zone.

Conodonts from the upper part of the Rapid Member suggest that this interval may belong to the lower *subterminus* Fauna, a probable equivalent of the Lower *disparilis* Subzone. Miospores recovered throughout the Rapid Member suggest assignment to the *optivus - triangulatus* Assemblage Zone of Richardson and McGregor (1986). It should be noted that the base of this zone compared to the associated conodont zonation, as recognized in the Iowa section, is slightly higher than that suggested by Richardson and McGregor (1986).

Conodonts are very rare and nondiagnostic in the Coralville Formation at the River Products Conklin Quarry. The same is true for the miospores. A thin coal in the Iowa City Member of the Coralville Formation, however, has produced and abundant miospore flora consistent with assignment to the *optivus - triangulatus* Assemblage Zone of Richardson and McGregor (1986), as is the case with the underlying Rapid Member of the Little Cedar Formation.

The miospores recovered from Lithograph City Formation at the Garrison Quarry also suggest assignment to the *optivus - triangulatus*, or possibly the *ovalis - bulliferus* Assemblage Zones of Richardson and McGregor (1986). Conodont information provided by Kralick (this guidebook) is consistent with this assignment.

The ranges of the miospores in the Iowa section are not in perfect agreement with those given by Richardson and McGregor (1986). They are, however, close enough to suggest that this zonation has biostratigraphic utility in the Iowa Devonian. On the other hand, there are serious discrepancies in these ranges compared with those given by Loboziak and Streel (1988). As a result of these discrepancies, their miospore zonation cannot, at present, be applied to the Cedar Valley Group of Iowa. This is not to say that their zonation is necessarily incorrect, but rather that more information about Devonian miospore ranges needs to be amassed before any zonation scheme can be adopted with confidence.

Other miospores, *Lophozonotriletes media* and *Retusotriletes phillipsii*, occur in the Iowa Devonian well below their reported occurrences elsewhere. The first occurrence of the former species was used as an indicator of a miospore zone of Frasnian age by Loboziak and Streel (1988). *R. phillipsii*, on the other hand, has been considered to be a Famennian indicator by Clendening, Eames, and Wood (1980). Both of these species, in Iowa, have been recovered from strata of Givetian age.

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TRILOBITES FROM THE LATE GIVETIAN SOLON MEMBER, LITTLE CEDAR FORMATION OF EASTERN IOWA AND NORTHWESTERN ILLINOIS

by

William Hickerson
Department of Geology
University of Iowa
Iowa City, Iowa 52242

INTRODUCTION

The stratigraphic occurrence and systematics of trilobites from the Solon Member of the Little Cedar Formation have long been in need of clarification. Cedar Valley Group trilobite diversity reaches its peak in these beds (Fig. 1), yet it has been little studied. James Hall (1888) redescribed the most characteristic Solon trilobite, *Dechenella prouti* in his monograph on Devonian trilobites. Norton (1899) listed Solon trilobites from Scott County, Iowa, including: *Dechenella prouti, D. rowi, D. clarus, Phacops rana* and *Crassiproetus crassimarginatus*. The holotypes of *Dechenella clarus* and *C. crassimarginatus* are from the Onondaga Group of New York, which is significantly older than the Solon. Specimens referred to these two species by Norton are probably better assigned to *D. prouti* and *C. arietinus*, and his *Phacops rana* is *P. iowensis iowensis*. Walter (1923) listed Norton's species and described the new Solon species *D.? nortoni* and *C. arietinus*. Delo (1935) described *Phacops iowensis* from a specimen collected from the Solon in Linn County, Iowa. The present paper addresses the biostratigraphy, taxonomy and taphonomy of Solon trilobites.

MATERIAL AND LOCALITIES

Trilobite collections in the Paleontological Repository of the University of Iowa (SUI); Putnam Museum, Davenport, Iowa; and Augustana College, Rock Island, Illinois were studied. Extensive new collections (see Appendices I and II) were made by the author at localities in Rock Island County, Illinois, and Scott and Johnson counties, Iowa. Rock Island localities include: Allied Quarry (SE 1/4, sec. 14, T.17N, R.2W), an abandoned quarry along Mill Creek (SE 1/4, Sec. 25, T.17N, R.2W), and "rip-rap" along the Mississippi River levee at Rock Island and Moline, Illinois. Solon and lower Rapid Member slabs that serve as "rip-rap" were quarried from the bed of the Mississippi River just upstream from Buffalo, Scott County, Iowa, during channel deepening operations by the U.S. Army Corps of Engineers. A much smaller collection was made at the outcrop immediately south of the Lake Macbride Spillway, Johnson County, Iowa (see Appendix I).

SOLON MEMBER STRATIGRAPHY AND ENVIRONMENTS OF DEPOSITION

The Solon Member in Rock Island County consists of approximately 2 m of fine to medium grained skeletal packstone, with argillaceous and bituminous or carbonaceous? partings. Bedding is irregular, blocky and locally fractured or brecciated as a result of dissolution of evaporite beds in the underlying Davenport Member of the Pinicon Ridge Formation (Anderson et al., 1982, Witzke et al. 1985). The basal contact is locally sandy (up to 20 cm thick at Buffalo Quarry) with stringers of chert sand extending into the underlying breccia. The Solon is separated from the overlying Rapid Member by a hardground surface. The upper 2/3 of the member in this area is a coral/stromatoporoid biostrome (*"profunda"* Zone, Stainbrook, 1941). The lower 30 cm is devoid of colonial corals and stromatoporoids, contains only rare solitary rugosans, but is rich in brachiopds, molluscs and trilobites. This bed is correlated with the *"independensis"* Zone (Stainbrook, 1941), which is well exposed in Johnson and Linn counties, Iowa.

The Solon Member in Johnson County is much thicker (6 m, see Fig. 2). Lithologically it has the same characteristics in Rock Island County. Several hardground surfaces are developed throughout the member and in places the upper contact with the Rapid is gradational.

TRILOBITES FROM THE GIVETIAN / FRASNIAN OF IOWA AND NORTHWEST ILLINOIS

LIME CREEK FORMATION
- Owen Member
  - *Scutellum* (*Scutellum*?) *thomasi* (Walter,1923)
- Independence Shale
  - *Harpidella*? *brandonensis* (Walter,1923)

CORALVILLE FORMATION
- Cou Falls Member
  - *Crassiproetus searighti* (Walter,1923)
  - *Dechenella* (subgenus *nov.*) sp.
  - *Mystrocephala raripustulosus* (Walter,1923)
  - *Phacops* sp.?

LITTLE CEDAR FORMATION
- Rapid Member
  - *Crassiproetus bumastoides* (Walter,1923)
  - *Crassiproetus occidens* (Hall,1861)
  - *Crassiproetus* n. sp.
  - *Dechenella* (subgenus *nov.*) n. sp. #2
  - *Phacops rana norwoodensis* (Stumm,1953)
  - *Greenops (Neometacanthus) barrisi* (Hall,1888)
  - *Greenops* (subgenus ?) *fitzpatricki* (Walter,1923)
  - *Greenops* (*Greenops*) n. sp.
- Solon Member
  - *Crassiproetus arietinus* (Walter,1923)
  - *Dechenella* (subgenus *nov.*) *prouti* (Shumard,1863)
  - *Dechenella* (subgenus *nov.*) n.sp. #1
  - *Dechenella* (subgenus *nov.*) *cf. D. rowi* (Green,1838)
  - *Dechenella*? *nortoni* (Walter,1923)
  - *Dechenella (Dechenella) cf. D. haldemani* (Hall,1861)
  - *Mystrocephala cf. M. pulchra* (Cooper and Cloud,1938)
  - *Cyphaspis* sp.
  - *Phacops iowensis iowensis* (Delo,1935)
  - *Greenops* (*Neometacanthus*) n. sp.
  - *Scutellum (Scutellum) depressum* Cooper and Cloud,1938

Figure 1. Trilobites thus far identified from the Givetian Coralville and Little Cedar formations and Frasnian Lime Creek Formation in eastern Iowa and northwestern Illinois.

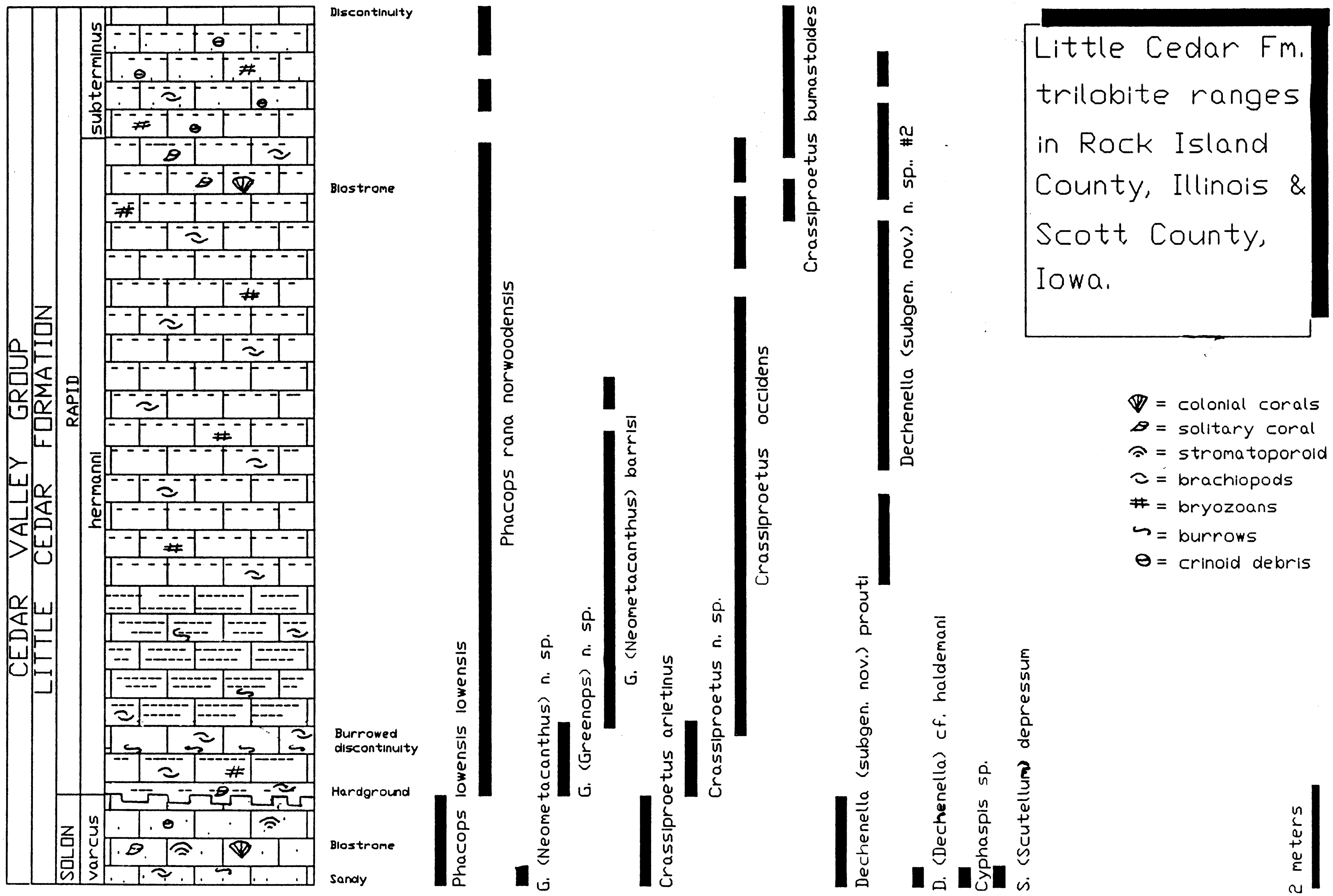


Figure 2. Stratigraphic ranges of Little Cedar Formation trilobites in Scott County, Iowa and Rock Island County, Illinois. Conodont zonation is displayed in far right column. Dashed intervals indicate rare occurrence.

The Solon Member was deposited during the beginning stages of a major transgression of open marine subtidal facies into the Midwest region (Taghanic Onlap, Johnson et al., 1985, Witzke, et al., 1988). Calcarenitic lithologies suggest that deposition was near or at wave base or that currents were sufficient to winnow lime mud. Many large colonial coral and stromatoporoid heads are overturned, perhaps by strong currents, periodic storms, or large fish (Witzke et al., 1988). Very large arthrodire placoderms (*Eastmanosteus*) reaching total lengths of over 4 m are present in these beds. Faunal diversity decreases in the upper part of the Solon, and this combined with the presence of calcareous algae and foraminifera, suggests that the Solon is a shallowing-upward sequence (Witzke et al., 1988).

The great diversity and abundance of trilobite specimens from the basal Solon Member in Rock Island County supports the hypothesis that this is the deepest part of the member. Trilobites are known to prefer the muddy, subtidal environments that are interpeted as the "deepest" water of a transgressive sequence. This relationship has been noted in both members of the Little Cedar Formation, trilobite numbers and diversity being highest at the base of the Solon and of the Rapid, as well as in the base of the Coralville Formation (Cou Falls Member). In each case, trilobites are most abundant directly above a discontinuity surface (erosional, burrowed, or hardground). The base of each of the above members is thought to represent the maximum transgression of that particular sequence (see Witzke et al., 1988, p. 246). Trilobites are rare to absent in the uppermost Solon in Rock Island County, although 3 species (*Crassiproetus arietinus* and *Dechenella prouti* far outnumbering *Phacops iowensis iowensis*, see Appendix I) are found in the top of the Solon at Lake Macbride. This, coupled with the abundance of large coiled nautiloids, may suggest a minor deepening event at the top of the member or that the initial pulse of the Taghanic Onlap began in the uppermost Solon.

LITTLE CEDAR TRILOBITE BIOSTRATIGRAPHY

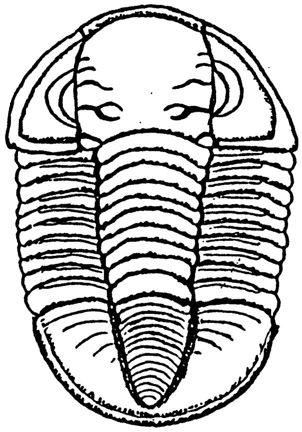
Two distinct trilobite faunas can be recognized in the Little Cedar Formation of eastern Iowa and west-central Illinois, a Solon assemblage and a Rapid assemblage (Fig. 2). The Solon assemblage (Fig. 3) is more diverse and includes at least 7 genera represented by 11 species. *Dechenella prouti* and *Phacops iowensis*

Figure 3. Solon trilobite association. 1. *Crassiproetus arietinus*, 2. *Scutellum (Scutellum) depressum*, 3. *Phacops iowensis iowensis*, 4. *Dechenella (Dechenella)* cf. *D. haldemani*, 5. *Cyphaspis* sp., reconstruction based on *C. craspedota*, 6. *Greenops (Neometacanthus)* n. sp., 7. *Dechenella*? *nortoni*, 8. *Dechenella* (subgen. *nov.*) *prouti*, 9. *Mystrocephala* cf. *M. pulchra*, reconstruction based on *M. pulchra*, thorax unknown; 10. *Dechenella* (subgen. *nov.*) n. sp. #1. All drawings X1.25 with the exception of #9 (X2.5).

iowensis are excellent index fossils for the member. The member contains a diverse dechenellid fauna, 3 different subgenera and possibly 6 species. *D. prouti* is common at "*profunda*" Zone exposures, but other species' (*D.* n. sp. #1, *D. cf. haldemani, D. cf. rowi*) are locally present. *D.*? *nortoni* and *D. (Dechenella)* sp. are present in the lower Solon "*independensis*" Zone. Some Solon trilobites can be used in regional correlations, *P. iowensis iowensis* occurring also in the lower Petoskey, Potter Farm and Thunder Bay formations of northern Michigan. Likewise, *Scutellum (Scutellum) depressum* occurs in the lower Petoskey Formation, Michigan; Cedar Valley Formation?, Calhoun County, Illinois; and the Canadian Arctic Islands (Ormiston, 1967). A similar species, *S. tullium*, is found in the Tully Formation of New York. Figure 2 shows the stratigraphic ranges of trilobite species in Rock Island County, Illinois, and Scott County, Iowa; similar ranges have been observed in Johnson County, Iowa. The cosmopoliton Solon trilobite fauna is similar to *varcus* Zone trilobite faunas in Europe and North Africa (Kielan, 1954; Morzadec, 1983 and 1988). Similar species of *Phacops, Greenops (Neometacanthus), Dechenella (Dechenella), Scutellum (Scutellum)* and *Cyphaspis* are present in Old World Givetian faunas. In Rock Island County, no Solon trilobite species has been found above the hardground surface that separates the two members of the Little Cedar Formation.

The more endemic Rapid Member assemblage occurs in association with conodonts of the *hermanni* and lower *subterminus* Fauna (Witzke et al., 1988). It is not as diverse as the Solon fauna, comprising 4 genera and 7 species. *Crassiproetus* (3 species) and *Dechenella* (subgen. *nov.*), which account for over 50% of Rapid species do not occur outside of North America. This is one of the youngest Middle Devonian trilobite faunas known in North America, having no equivalents in New York. Givetian strata from northern Michigan (e.g. upper Petoskey) that has previously

SOLON TRILOBITE ASSOCIATION



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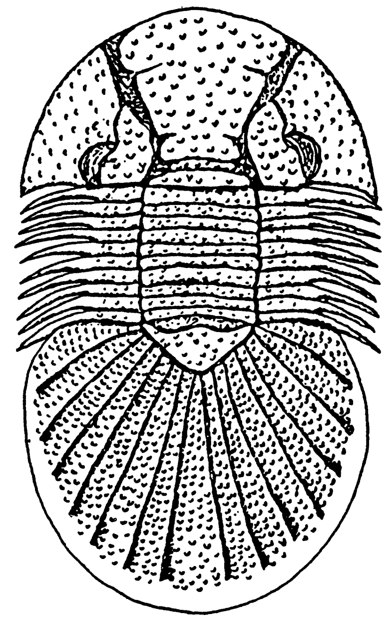

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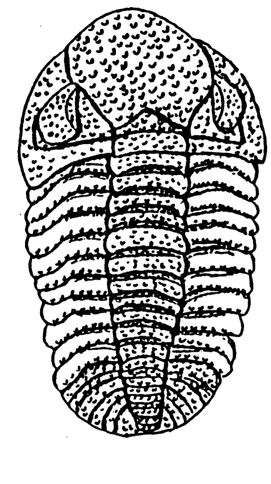

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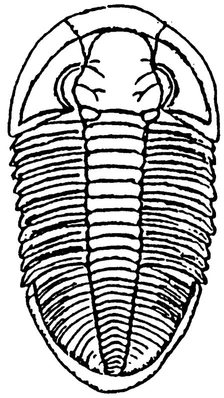

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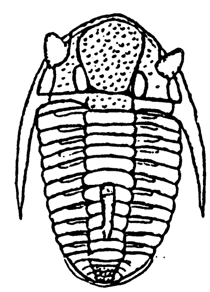

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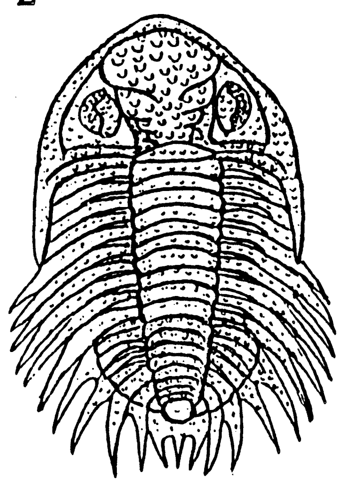

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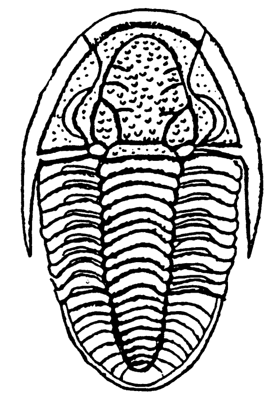

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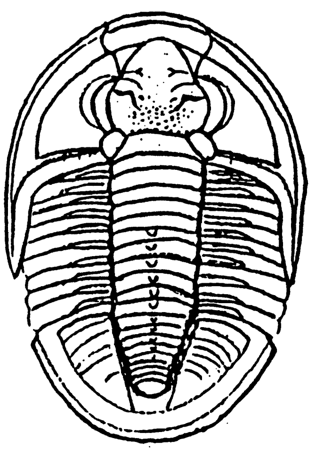

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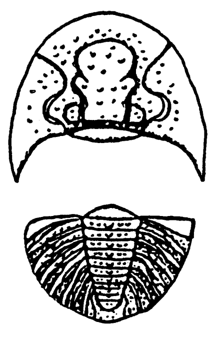

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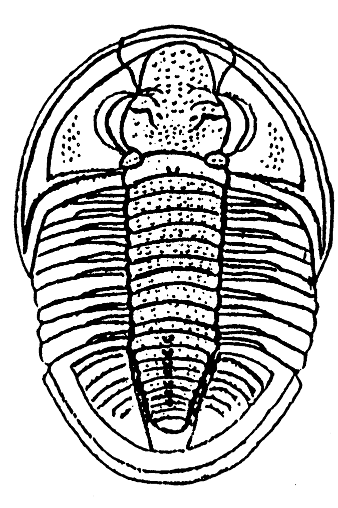

10

been assigned to the *varcus* Zone may in fact be younger and are in need of restudy (Witzke, personal communication). At the base of the Rapid, *Phacops iowensis iowensis* is replaced by *P. rana norwoodensis*, *Crassiproetus arietinus* by *Crassiproetus* n.sp. and *Greenops (Neometacanthus)* n.sp. by *G. (Greenops)* n.sp. The lower half of the Rapid, below the coral biostrome, is dominated by phacopids (*Phacops, Greenops, Neometacanthus*), whereas proetids (*Crassiproetus, Dechenella* (subgen. *nov.*)) are much more abundant in the higher energy crinoidal beds of the upper half of the Rapid Member. Hamilton Group trilobites (Speyer and Brett, 1986) display the same distribution pattern; proetids are common in the shallower water facies, whereas phacopids dominate the deeper, basinal facies. *Greenops (Neometacanthus) barrisi* is the last species of the Dalmanitidae occurring in the Midcontinent, the upper Rapid biostrome marks the extinction of this family in North America. *Phacops* occurs only rarely above the biostrome and is known (questionably) from a couple of specimens from the lower Coralville Formation.

FRASNIAN GAP IN MIDCONTINENT TRILOBITE RECORD

Trilobites are conspicously absent or rare in Frasnian Midcontinent deposits. The two trilobites reported from the Frasnian (Fig. 1) are poorly known. *Harpidella? brandonensis* is known only from an isolated cranidium that lacks precise locality and stratigraphic data, whereas *Scutellum thomasi* is represented by a single cranidium and one pygidium. No trilobites are known from the Iowa City Member of the Coralville Formation or the Lithograph City and Shell Rock formations. This is perplexing, given the occurrence of brachiopod/mollusc/solitary rugose coral dominated facies in the above formations, and the fact that comparable assemblages yield abundant trilobites in the lower part of the Little Cedar Formation. Additionally, diverse trilobite faunas are known from the Famennian Louisiana Limestone of northeastern Missouri and western Illinois; and from lower Mississippian (Kinderhookian) strata in the Midcontinent (Brezinski, 1986). In Europe and North Africa, trilobites (including phacopids, proetids, scutellids and asteropygids) are common and diverse in Frasnian strata and some species are important as biostratigraphic indicators.

Possible explanations for the paucity of trilobites in the Midcontinent include: 1) predation by fish and cephalopods, 2) displacement by other arthropod groups, 3) insufficient sampling in Frasnian formations, and 4) unfavorable environments. Predation by fish (placoderms, dipnoans, crossopterigians) or cephalopods seems unlikely, considering that the same genera and in some cases the same species of these two groups are present in the trilobite-rich Little Cedar. Additionally, if trilobite numbers were sufficient to support these predators, moulted exoskeletons and isolated sclerites should be present. There is no evidence to suggest that trilobites were outcompeted by some other arthropod group, as the only common arthropod remains found in these formations are small ostracodes and branchiopods. The prospect that trilobites are present, but have yet to be collected is remote. Large collections of fossils from the Frasnian formations have been made and the macro-faunas are well known. The most likely explanation is that environmental conditions were not favorable. As was mentioned before, trilobites are most abundant and diverse in strata deposited during the maximum transgression of a given sequence (e.g. Brezinski, 1986). A comparison of the relative abundance and diversity of trilobites with the qualitative sea-level curve for Cedar Valley deposition (Witzke et al. 1988, fig. 13) supports this interpetation. Regressive (or restricted environment) units within the Cedar Valley Group (i.e. the Solon coral-stromatoporoid biostrome, upper Rapid biostrome, Hinkle Member of the Little Cedar Formation and the Iowa City Member of the Coralville Formation) are devoid of or contain only few trilobite remains. Additionally, the absence of trilobites from the Lithograph City and Shell Rock formations may be explained, in part, by the shallower water, stromatoporoid-rich, higher energy environments of deposition. However, this depth-dependent hypothesis does not explain the rarity of trilobites in the Lime Creek Formation, whose argillaceous limestones, that are well exposed at Rockford in Cerro Gordo County, Iowa, would appear ideal for trilobites. The fauna contains abundant and diverse brachiopods, molluscs and solitary rugose corals that were deposited in a subtidal environment similar to that of the lower part of the Rapid Member, yet it lacks trilobites.

TRILOBITE ASSOCIATIONS

Four distinct trilobite associations occur in the Little Cedar Formation of eastern Iowa and northwestern Illinois. These associations are defined with respect to 1) trilobites species composition, 2) lithology of associated sediment, 3) associated fauna, and 4) trilobite taphonomy. The four trilobite associations are, in ascending order: 1) Solon, 2) basal Rapid, 3) middle Rapid, and 4) upper Rapid. Only the Solon association is discussed in detail in the present paper (see Hickerson, 1989, for discussion of other Little Cedar trilobite associations).

Solon Trilobite Association

In Rock Island and Scott counties, *Dechenella prouti* and *Phacops iowensis iowensis* are the dominant trilobites in the Solon Member (see Appendix I). *Greenops (Neometacanthus)* n.sp. and *Crassiproetus arietinus* are less common, and *Scutellum depressum, Dechenella (Dechenella)* cf. *haldemani, D.* oral *is relatively common* and an uniden*tified solitary rugos*an cf. *pulchra,* and *Dechenella* n.sp. #1 occur locally in this association in Johnson, Benton, Buchanan, and Linn counties. *P. rana norwoodensis* was questionably listed by Eldredge (1972) as occurring in the Solon Member, but this could not be confirmed in the present study.

Lithology

In Rock Island County, the Solon Member is dominated by fine-grained skeletal packstones with minor wackestones and stromatoporoid boundstone. Bedding is massive or blocky, but weathered blocks may split along bituminous or carbonaceous partings into thin slabs. The unit is locally fractured or brecciated, and the basal 8-10 cm is sandy in places. At Mill Creek and Allied Quarry, an indistinct burrowed (*Planolites*) discontinuity surface occurs approximatly 25 cm above the Solon/Davenport contact. At Lake Macbride, Johnson County, lithologies of the studied trilobite bed are similar. The main differrences are that: 1) the section is much thicker (6 m as opposed to 2 m), 2) several discontinuous hardground surfaces are present, and 3) the trilobites were collected from above the "*profunda*" biostrome rather than below it.

Associated Fauna

In Rock Island and Scott counties the lower 75 cm of the Solon Member is characterized by brachiopods and common molluscs. Atrypids: *(Independatrypa independensis, Spinatrypa occidentalis*), the pentamerid *Gypidula comis*, and the productid *Productella belanskii* occur as isolated specimens or in large monospecific *in situ* clusters (50-100+ individuals). Other common brachiopods include: *Hypothyridina intermedia, Orthospirifer iowensis* and *Schizophoria meeki.* Molluscs are represented by platycerid, bellerophonid and euomphaluid gastropods; nautiloids: *Acleistoceras? walshi, A.? gigantea, Centroceras pratti* and *Tetranodoceras ornatum*; bivalves: unidentified nuculids and pteriods. Crinoid debris and corals are conspicuously rare, considering their abundance in overlying beds. One species of a branching auloporid? coral is relatively common and an unidentified solitary rugosan is locally present. Other faunal elements from the basal Solon include: common fenestellid bryozoans, rare conulariids and placoderm debris (*Rhynchodus, Eastmanosteous*). No attempt was made to identify the microfauna.

The upper 1.5 m of the Solon Member is dominated by, and on some bedding planes consists almost entirely of, corals (*Astrobillingsa, Favosites*, branching tabulates, solitary rugosans), sponges (*Astraeospongia*), and laminar stromatoporoids. Crinoid debris is abundant, and cranial plates of the large (up to 4 m) arthrodire *Eastmanosteus pustulosus* are present. The holotype of this large predator is from near Allied Quarry, Rock Island, Illinois. Macrofossils associated with trilobites at the Lake Macbride site include brachiopods (*Cranaena* sp.), platycerid and euomphaluid gastropods, nautiloids, scaphopods, rostroconchs and fish debris.

Trilobite Taphonomy

The following taphonomic interpetations are based on the many specimens collected in Rock Island and Scott counties. Similar occurrences have been noted at the Lake Macbride Spillway outcrop, but the trilobite database for that locality must be enlarged before general conclusions can be reached.

In Rock Island and Scott counties, basal Solon Member (lower 75 cm) trilobites occur as isolated sclerites, complete exoskeletons (enrolled, reflexed or outstretched, Appendix I) and moult ensembles. Trilobites commonly occur in monospecific body clusters (67%, Appendix II). *Dechenella prouti* body clusters dominate, comprising 70% of all monospecific clusters. Body clusters usually have isolated sclerites associated, and include complete outstretched and enrolled individuals as well as specimens in various stages of disarticulation (Appendix II). The number of specimens in a cluster ranges from 3 to 22. *Phacops iowensis iowensis* and *Greenops (Neometacanthus)* n. sp. were also found in monospecific body clusters. All mixed trilobite species clusters are dominated by one species, generally *D. prouti*, but clusters dominated by *P. iowensis iowensis* and *G. (Neometacanthus)* n. sp. are encountered, less commonly. A large mixed cluster (20 specimens) recently collected contains 15 *D. prouti* (2 complete outstretched, 4 enrolled, 2 with cephala and thorax, 5 pygidia and 2 free cheeks), 4 *P. iowensis iowensis* (1 enrolled, 2 cephala and 1 pygidium), and a *Scutellum depressum* pygidium. All broken enrolled trilobites examined were filled with sediment, but a few tightly enrolled, uncrushed specimens are probably filled with calcite spar. The ratio of inverted to convex up outstretched specimens appears to be nearly equal.

Biostratinomic features in the basal Solon, including complete enrolled and outstretched trilobite exoskeletons, nuculid bivalves in life position perpendicular to bedding surfaces, and *Spinatrypa occidentalis* with attached spines, strongly suggests rapid burial of organisms with little or no postmortem displacement. Multi-element skeletons of arthropods can only be preserved intact if individuals are buried very rapidly, usually within hours (Speyer, 1987). Arthropods can escape rapid burial, suggesting that the trilobites were killed or immobilized prior to burial, or they were deeply buried (Speyer, 1985; Speyer and Brett, 1986), in this case by lime mud, making escape impossible.

The upper 1.5 m of Solon in the study area is dominated by the "*profunda*" coral/stromatoporoid biostrome and has yielded only a few fragmentary specimens of *Dechenella prouti*, *Crassiproetus arietinus* and *Phacops iowensis iowensis*. The mollusc/trilobite biofacies that occurs above the biostrome at Lake Macbride is absent in the Quad-City area.

Conclusions

Eleven species of trilobites, represented by seven genera, are recognized from the Solon Member of the Little Cedar Formation, Cedar Valley Group of eastern Iowa and northwestern Illinois. This assemblage is one of the most diverse Devonian (Givetian) trilobite faunas known from the North American Midcontinent. The paucity of trilobites in overlying Frasnian formations is probably related, in part, to lowered sea-level.

A large collection from Rock Island County, Illinois, and a small sample from Johnson County, Iowa, reveals previously unknown biostratigraphic and taphonomic data. Characteristics of Solon trilobites are: 1) restricted stratigraphically to that member, 2) common occurrence as complete exoskeletons, 3) complete specimens occur predominately in clusters of from 3 to 22 specimens, 4) most abundant in mollusc/brachiopod biofacies above and below the "*profunda*" biostrome, 5) dominated by proetids (dechenellids) at most localities, 6) attained a larger size than their Rapid Member generic counterparts, and 7) possess more tuberculate exoskeletons than Rapid species (see Systematic Paleontolgy section).

SYSTEMATIC PALEONTOLOGY

The diverse trilobite fauna of the Solon Member of the Little Cedar Formation includes the families: Proetidae, Dechenellidae, Aulacopleuridae, Brachymetopidae, Phacopidae, Dalmanitidae and Scutelluidae. Eleven species are represented, of which at least 3 are new and are discussed herein. Abbreviations used in this section include: SUI, University of Iowa paleontological collections; 1p, 2p, 3p refers to the lateral glabellar furrows, numbered posteriorly-anteriorly; (trans.), transverse; and (sag.), sagittal.

Family PROETIDAE Salter, 1862
Subfamily CRASSIPROETINAE Osmolska, 1970
Genus *CRASSIPROETUS* Stumm, 1953
Type species: *Proetus (Crassiproetus) traversensis* Stumm, 1953
Diagnosis: "Cephalon semicircular, typically with a narrow brim. Glabella smooth, highly convex, nearly as wide as long. Glabellar furrows obsolete except as very faint depressions or color markings on some species. Free cheeks with a convex ocular platform, of large size in some species, and with rounded genal angles. Pygidium long, highly convex, and with many weakly defined segments on axis and pleurae. Test punctate or minutely granulose"(Stumm, 1953).

CRASSIPROETUS ARIETINUS (Walter, 1923)
Figure 3, Number 1
Proetus arientinus Walter, 1923, p. 297-299, plate XXV, figures 21,22.
Proetus crassimarginatus, Walter, 1923, p. 303.
Cornuproetus calhounensis Cooper and Cloud, 1938, 455-457, plate 55.
Crassiproetus arietinus(?), Hickerson, 1989, p. 32, figure 2.8.

Holotype: SUI 9122, Cedar Valley Formation, Johnson County, Iowa.
Description: Cephalon rounded, convex with narrow border. Four pairs of glabellar furrows present as color markings or shallow impressions on exfoliated

specimens, 1p furrow bifurcate. Occipital lobes small, but distinct. Surface of glabella marked by faint, transverse, lamellose lines. Free cheeks bluntly rounded, eyes small. Thorax with 10 segments. Pygidium semielliptical in outline, axis prominent, elevated above pleurae and tapering to a narrow termination near the margin. Border of pygidium indistinct (see Walter, 1923 for complete description).

Measurements: Holotype, length of cephalon 15 mm, length of thorax 13 mm, length of pygidium 12 mm and width across genal angles 19 mm.

Stratigraphic occurrence and localites: Solon Member, Rock Island and Calhoun counties, Illinois; Johnson, Scott and Linn counties, Iowa.

Discussion: The holotype of this species is a highly weathered, but complete specimen that does not show the diagnostic features of either the pygidium or glabella; however, the paratype cranidia (SUI 9123 and 9124) of this species display the diagnostic characters. Distinguished from all other Cedar Valley Crassiproetinae by narrow cephalic border, ornamentation of glabella and indistinct pygidial border. *C. calhounensis* from strata possibly equivalent to the Solon Member in Calhoun County, Illinois, is here considered a junior synonym of *C. arietinus*. Listed diagnostic characteristics of Cooper and Cloud's (1938) species' are the same as those for *C. arietinus*, and the cranidium and pygidium they illustrate (plate 55, p. 457) appears to be identical to *C. arietinus*. *C. arietinus* locally dominates the Solon trilobite association; one such locality is 3 feet below the Solon/Rapid contact at the outcrop just south of the Lake Macbride spillway, Johnson Co., Iowa (see Appendix I).

Subfamily DECHENELLINAE Pribyl, 1946

Genus *DECHENELLA* Kayser, 1880

Subgenus *DECHENELLA (DECHENELLA)* Kayser, 1880

Type species: *Phillipsia verneuili* Barrande, 1852

Diagnosis: "Glabella expanded across (trans.) basal lobes with distinct constriction oppposite the 2p furrow, tapering anteriorly, outline thus subconical to cloverleaf-shaped. Three to four pairs of moderately deep to deep lateral glabellar furrows, 1p with adaxial branch. Anterior branch of facial suture strongly divergent, angulated at border furrow. Preglabellar field typically short (sag.). Occipital lobes prominent. Pygidium elongate and multisegmented, long, tapering axis with thirteen to nineteen rings; eight or more pleural ribs. Interpleural furrows usually present. Pygidial bordere present" (Ormiston, 1967).

***DECHENELLA (DECHENELLA)* CF. *D. HALDEMANI* (Hall, 1861)**

Figure 3, Number 4

Proetus haldemani Hall, 1861, p. 74.

Dechenella haldemani, Kayser, 1880, p. 707, plate XXVII, figure 9.

Proetus haldemani, Hall, 1888, p. 113, plate XXI, figures 7-9, plate XXIII, figures 13-15.

Proetus haldemani, Walter, 1923, p. 295-297, plate XXV, figures 18,19.

Description: Cephalon semicircular in outline; border broad, flat. Border furrow narrow in front, wider and shallower posteriorly. Glabella pair-shaped, 3 pairs of posteriorly curved lateral glabellar furrows. 1p furrow bifurcate. Occipital lobes small. Palpebral lobes prominent, eyes of medium size. Free cheeks terminating in sharp genal angles, but not spinose. Thorax composed of 10 segments. Pygidium subelliptical in outline, convex, axis elevated. Border well defined. Axis composed of 12 to 14 annulations, 8 to 10 pleurae present (see Walter, 1923 for complete description).

Measurements: SUI 9092, length of cephalon 8 mm, length of thorax 11 mm, length of pygidium 7.5 mm and width across genal angles 13 mm.

Stratigraphic occurrence and localities: Solon Member, Rock Island County, Illinois; Scott, Johnson, Buchanan and Linn counties, Iowa.

Discussion: Walter (1923) assigned this material under review to *Proetus haldemani*, which occurs in the Hamilton Group of New York and Pennsylvania. At that time the Cedar Valley was thought to be a direct correlative of the Hamilton and many genera were assigned to Hamilton species. Ormiston, in 1971, examined all SUI repository specimens of *Dechenella (Dechenella)* from the Solon Member and recognized 2 different species: *D. (Eudechenella) haldemani* (SUI 9096) and *D. (Eudechenella)* n. sp. #1 (SUI 9094). Solon material assigned to this species needs to be compared closely to the type specimens from the Hamilton before a final determination can be made. The subgenus is rare, represented by 10 SUI specimens and only 4 specimens of a total of 271 trilobites collected in the large sample from the basal Solon in Rock Island County (see Appendix I).

DECHENELLA (SUBGENUS *NOV.*)

Diagnosis: Glabella more highly convex than *D. (Dechenella)*, less constricted anteriorly. Three pairs of lateral glabellar furrows are present as color marking, not incised like *D. (Dechenella)*. Occiptal lobes large, prominent. Axial nodes present on the thorax and pygidium of most species. Pygidium short and convex with fewer axial annulations and pleurae than *D. (Dechenella)*. Exoskeleton ornamentation ranges from granular to tuberculate. Stumm (1953) assigned several Michigan and New York species with the above characteristics to the subgenus *Basidechenella* (Richter, 1912). It has been pointed out by Richter and Richter (1950) and Ormiston (1967) that these North American Dechenellinae do not conform entirely to the origional concept of the subgenus *Basidechenella*. The European *Basidechenella* has occipital lobes that are not entirely separated from the occipital ring, whereas North American species previously assigned to this subgenus have large, prominent, completely separated occipital lobes. It is probable that these North American species represent a new, undescribed subgenus. Previously described North American species that should be included in this new subgenus are: *D. rowi*, Hamilton Group; *D. clara*, Onondaga Group; *D. lucasensis*, Silica Shale; *D. nodosa, D. pulchra, D. reimanni* and *D. witherspooni*, Traverse Group; *D. prouti*, Cedar Valley Group, and *D. nevadae*, Nevada Formation.

DECHENELLA (SUBGENUS *NOV.*) *PROUTI* (Shumard, 1863)

Figure 3, Number 8

Proetus prouti Shumard, 1863, p. 110.

Proetus davenportensis Barris, 1878, p. 287, plate XI, figure 8.

Proetus prouti, Hall, 1888, p. 126, plate XXIII, figures 16-18.

Proetus prouti, Walter, 1923, p. 283-286, plate XXV, figures 5,8.

Proetus clarus, Walter, 1923, p. 289-291, plate XXV, figures 12,13.

Dechenella elevata Cooper and Cloud, 1938, p. 453-455, plate 55, figures 20-22, 24-27.

Dechenella (Basidechenella) prouti, Hickerson, 1989, p. 32, figure 2.7.

Holotype: Lost in Great St. Louis fire.

Description: Cephalon semicircular, convex. Glabella conical, 3 pairs of posteriorly curved lateral glabellar furrows present as color markings. 1p and 3p glabellar furrows bifurcate, anterior branch of 1p furrow has a small "gap". Glabellar ornamentation consists of numerous small tubercles at the base, becoming fewer in number and then obsolete anteriorly. Frontal border wide, flattened, bearing two furrows separated by a low ridge. Free cheeks terminating in long genal spine that reaches the 6th or 7th thoracic segment. Occipital lobes large, prominent. Thorax composed of 10 segments with axial nodes on the posterior 4 or 5 annulations. Pygidium semicircular in outline, wider than long. Axis elevated tapering abruptly to a termination well inside of the border. Axis is composed of 10 annulations with the anterior 6 bearing an axial node with a small posteriorly directed spinule (for complete description see Hall, 1888).

Measurements: SUI 9089, length of cephalon 14 mm, length of thorax 15 mm, length of pygidium 13 mm and width across genal angles 24 mm.

Stratigraphic occurrence and localities: Upper Solon beds ("*profunda*" Zone), Rock Island County and Calhoun counties, Illinois; Scott, Johnson, Buchanan and Linn counties, Iowa.

Discussion: This taxon has a long and interesting history. The original type specimen of *Proetus prouti* described by Shumard was destroyed along with the rest of his collection in the St. Louis fire. W.H. Barris described *P. davenportensis* from material collected from the Solon at Davenport; he subsequently loaned his specimens to James Hall who recognized these specimens belonged to Shumard's species. Hall redescribed *D. prouti* in his great monograph on Devonian trilobites. W.H. Norton (1899) made collections from the Solon Member in Scott County and listed *D. prouti* and *D. clarus*. These species were also described in O.T. Walters paper. It is the author's opinion that both species listed by Norton and Walter are actually *D. prouti*. The holotype of *D. clarus* is from the Onondaga Limestone, which is significantly older than the Solon. Preservational factors, intraspecific variation or sexual dimorphism combined with the fact that these beds were thought to be "Corniferous" in age probably led to this misidentification. A large number (121) of specimens of *D. prouti* were collected in Rock Island County (see Appendix I). The degree of deformation occurring during sediment compaction is dependent on the lithology of that particular bedding plane. Some specimens are compressed in a anterior-posterior direction, thereby increasing the original convexity.

Conversely dorsal-ventral deformation made the exoskeleton wider and flater. Adding to the confusion is the fact that characters such as genal spine length, glabellar ornamentation and occurrence and prominence of axial nodes appear to be quite variable in this species. The genal spines become proportionally longer with age; in the smallest specimens they reach the 6th thoracic segment, in average sized individuals they reach the 7th segment, and in the largest specimen extends all the way to the 9th segment. Most cephala display fine tuberculation on the posterior portion of the glabella, but this feature is absent or not preserved in others. Axial nodes are prominent on the last 4 or 5 thoracic segments and the first 5 or 6 segments on the pygidium of most individuals, but are faint or even lacking on others. A trilobite worker who uses such characters as specific differences could recognize 3 or 4 species in Solon samples. However, it is the author's opinion, considering all of these specimens come from the basal 75 cm of the Solon, that these differences can be attributed to intraspecific variation or sexual dimorphism. *D. prouti* is an excellent index fossil for the Solon Member, and is the most common trilobite collected at the majority of localities. *D. elevata* from a Cedar Valley? outlier in Calhoun County, Illinois, is here considered a junior synomym of *D. prouti.* Cooper and Cloud (p. 455) stated that *D. elevata* differs from *D. prouti* by having a shorter genal spine, "that of *D. prouti* reaching to the eighth or ninth thoracic segment", as mentioned above this character is variable. *D. elevata* also has 6 nodes on the pygidial axis and the same distribution of small tuberacles on the posterior portion of the glabella. Given the variability of these features in *D. prouti* and the fact that these beds in Calhoun County may correlate with the Solon Member, and do contain other Solon trilobites, *D. elevata* is probably synonymous with *D. prouti.*

DECHENELLA* (SUBGENUS *NOV.*) CF. *D. ROWI (Green, 1838)

Calymene rowi Green 1838, p. 406.

Proetus rowi, Hall 1861, p. 75.

Proetus rowi, Hall 1888, p. 119, plate XXI, figures 2-6, 24-26, plate XXIII, figures 20-29.

Proetus rowi, Walter, 1923, pp. 291-294, plate XXV, figures 14,15.

Dechenella (Basidechenella) rowi, Stumm, 1953, p. 120, plate III, figure 11.

Description: Cephalon semicircular in outline, strongly convex, frontal border not preserved. Glabella large, convex, broadly conical, broadly rounded in front. Lateral glabellar furrows indicated by 3 extremely faint lines with the 1p furrow bifurcate. The posterior portion of the glabella is covered by minute tubercles, with a small number of somewhat larger tubercles clustered together medially. Palpebral lobes prominent, eyes large. Free cheek elevated, genal spines not preserved. Thorax with 10 segments and a wide axis. Pygidium not preserved (for complete description see Walter, 1923).

Measurements: SUI 9129, Solon Member, Davenport, Iowa. Total length 44mm, width 20 mm.

Stratigraphic occurrence and localities: Solon Member, Scott County, Iowa.

Discussion: Only one specimen of this species is known. It is probably a member of the same subgenus as *D. prouti,* but differs from that species by possessing a much wider anterior portion of the glabella and a wider thoracic axis. Walter assigned this specimen to *D. rowi,* but it cannot be compared fully to that species without details of the cephalic frontal border, genal spines and pygidium.

***DECHENELLA* (SUBGENUS *NOV.*) N. SP. #1**
Figure 3, Number 10

Description: Cephalon semicircular, convex with a moderately wide frontal border bearing narrow ridge that runs parallel to the edge of the cephalon. Glabella convex, tapering anteriorly with a slight contriction directly in front of eyes. Three pairs of lateral glabellar furrows present, directed posteriorly with 1p and 3p furrows bifurcating. Entire glabella covered with medium sized tubercles with smaller tubercles scattered among them. Eight to ten of the larger tubercles are clustered together in a medial position at the posterior edge of the glabella. Palpebral lobes large, flat, not tuberculate; eyes large, lunate. Free cheeks with weakly tuberculate ocular platform terminating in a short genal spine that extends to the 4th thoracic segment. Occipital lobes large bearing 5 or 6 tubercles, occipital ring finely tuberculate and bears an axial node. Thorax with 10 segments, axis tuberculate. Pygidium short, relatively wide, moderately convex. Axis with 10 segments, the first 6 or 7 bearing a small axial node. 6 or 7 pleurae indicated, each bearing a row of small tubercles on their posterior margins.

Stratigraphic occurrence and localities: Solon?

Member, Coralville Dam spillway, Johnson County, Iowa.

Discussion: Only two specimens are known, one a complete enrolled specimen (SUI 40158) was collected by Diane Corcoran at the Coralville Dam spillway. The specimen was found on a loose slab in the Iowa River below the spillway. Another inverted, but complete outstretched exoskeleton (SUI 34483) from the same locality, displays the short genal spines and axial tuberculation characteristic of this new species. The Coralville Formation and Rapid Member of the Little Cedar Formation outcrop in the bluffs above this locality, but no Solon strata has been observed above the water level. However, the matrix surrounding the specimen is similar to typical Solon lithologies and the preservation of the trilobite is like that of Solon specimens. It is conceivable that the river has cut down into the uppermost Solon directly below the spillway or perhaps this slab was transported to this locality by other means. It is sometimes difficult to discern Solon from Coralville lithologies in hand samples, therefore, this species' inclusion in the Solon fauna is tentative.

It differs from all other Cedar Valley Dechenellinae of this subgenus by possessing coarser tuberculation over most the cephalon, an axial node on the occipital ring, and a short genal spine. It is similar to *D. nodosa*, *D. pulchra*, and *D. reimanni* (all Stumm, 1953) from the Traverse Group of Michigan, all of which have the characteristic tuberculate cephalon. *D.* n.sp. #1 differs from them in having a much shorter genal spine and lacking axial nodes on the thorax. Additionally, the lateral glabellar furrows are indistinct on *D. nodosa* and *D. pulchra* and apparently lacking on *D. reimanni.*

DECHENELLA ? NORTONI (Walter, 1923)
Figure 3, Number 7
Proetus nortoni Walter, 1923, p. 286-289, plate XXV, figures 9-11.

Holotype: SUI 9095, Solon Member, Linn Junction, Linn County, Iowa.

Description: Cephalon semicircular in outline. Frontal border wide with thickened, recurved edge. Glabella elongate, pair-shaped with narrowing at anterior edge of the eyes. Three pairs of posteriorly directed, deeply incised lateral glabellar furrows are present. 1p glabellar furrow bifurcates, with the posterior branch meeting the occipital ring, thus isolating the 1p lobe. Glabella coarsely tuberculate. Occipital lobes well developed, small. Palpebral lobes prominent, eyes of medium size, lunate. Free cheeks terminate in long genal spine that reaches the 7th thoracic segment. Thorax with 10 segments. Pygidium semielliptical, nearly twice as wide as long. Border is thickened, axis raised above pleurae tapering to an obtuse termination inside border. Axis composed of 14 segments with 10 defined pleurae (see Walter, 1923, for complete description).

Measurements: Holotype, length of cephalon 12 mm, length of thorax 14.5 mm, length of pygidium 10 mm, and width across genal angles, 20 mm.

Stratigraphic occurrence and localities: Solon Member, Johnson, Buchanan and Linn counties, Iowa.

Discussion: The author knows of only 4 specimens of this unique dechenellid. Besides the holotype, there are two other SUI specimens, one complete enrolled (SUI 9094) and a cranidium (SUI 9098). Additionally, the author collected a pygidium *in-situ* from the top of the *"independensis"* Zone at the Lake Macbride spillway. SUI 9098 is associated with *Independatrypa* on the same slab and may also be from that zone.

D. ? nortoni does not closely resemble any other figured North American dechenellid. Its glabella is pair-shaped, like the subgenus *D. (Dechenella),* but no other North American member of that subgenus has the strong tuberculation, long genal spine, complete separation of the 1p glabellar lobe and thickened pygidial border. The species differs significantly from *Dechenella* (subgenus nov.). More study is needed, but the author's suggests that this species may belong in the Schizoproetinae, which occurs in the Givetian of Europe and the Canadian Arctic Islands (see Ormiston, 1967). Schizoproetinae are characterized by separation of 1p glabellar lobes.

Family AULACOPLEURIDAE Angelin, 1854
Genus *CYPHASPIS* Burmeister, 1843
Type species: *Phacops ceratophthalmus* Goldfuss, 1843
Diagnosis: "Aulacopleurine with strongly inflated glabella which projects over short (sag.) preglabellar field in dorsal view; thorax of eleven segments with axial spine on the sixth, prominent "boss" on anterior pleural band at inner edge of articulating facet, which is about halfway along pleura; pygidial axis short and wide, anteriorly as wide as pleural areas; interpleural furrows only weakly developed" (Thomas and Owens, 1978).

***CYPHASPIS* SP.**
Figure 3, Number 5

Description: Cranidium highly convex, frontal border narrow, raised, bearing a marginal row of low indistinct nodes. Facial suture also exhibits minute nodes along its edge. Glabella strongly inflated and moderately tuberculate, glabellar lobes not preserved. Free cheeks and thorax unknown. Pygidium with 5 distinct segments, 3 pleurae and a well defined border. Each axial ring bears a row of tubercles that become more prominent on each successive ring until the 4th ring, which has the largest tubercles, the last ring is faintly tuberculate.
Measurements: length of cranidium 7.5 mm, width of cranidium 7 mm, length of pygidium 4.8 mm and width of pygidium 7.5 mm.
Stratigraphic occurrence and localities: Solon Member, Rock Island County, Illinois.
Discussion: *Cyphaspis* sp. is the only member of this genus occurring in the Devonian of Iowa or Illinois. Known from one specimen that appears to be the remains of a single individual, the cranidium, pygidium and other unidentifiable fragments occur within millimeters of each other on a small slab from the base of the Solon. Stumm (1953) did not include this genus in his list of trilobites from the Traverse Group. Closest relatives of this species are *C. spinafrons* (Williams, 1935) from the Tully Formation and *C. craspedota* Hall (1888) from the Hamilton Group of New York. *C. spinafrons* differs by having a narrower pre-glabellar field, coarser tuberculation on cephalon and double row of spines along the edge of the frontal border. The Solon specimen exhibits glabellar tuberculation, lack of border spines and pygidial ornamentation similar to *C. craspedota.*

Subfamily BRACHYMETOPIDAE Prantl and Pribyl, 1951
Genus *MYSTROCEPHALA* Whittington, 1960
Type species: *Cordania pulchra* Cooper and Cloud, 1938
Diagnosis: "Cephalon differs from that of *Cordania* in that lateral glabellar furrow 2p is deeper and longer, and lateral glabellar lobe 2p is gently convex; cheek and preglabellar field is concave distally with upturned edge, and lacks the broad, convex border; anterior branches of sutures strongly divergent (at 70 degrees to mid-line, i.e. less than in some species of *Cordania*). Rostral plate and hypostome unknown. Thorax unknown. Pygidium differs from that of *Cordania* in that anterior pleural bands, which are present on the first six or seven segments, are low and do not extend on to outer parts of pleural regions, whereas posterior pleural bands are prominent and extend to margin" (Whittington, 1960).

MYSTROCEPHALA* CF. *M. PULCHRA (Cooper and Cloud, 1938)
Figure 3, Number 9
Proetus sp., Walter, 1923, p. 303, plate XXV, figure 20.
Cordania pulchra Cooper and Cloud, 1938, p. 457-458, plate 55, figures 28,29, 31-34.
Mystrocephala pulchra, Whittington, 1960, p. 414-415, plate 53, figures 15,16, 19, 22-26.

Description: This species represented by only a fragmentary pygidium. Axis unknown, portion of right pleural lobe well preserved. The pleurae slope moderately from axis to a broad, shallow concave border. Pleural region divided by eight strong bands that extend to the margin. These bands bear an indistinct row of pustules on their crests. Bands are separated by broad, shallow grooves (see Walter, 1923, for complete description).
Measurements: SUI 9104, length of pygidium 6 mm and width 9 mm.
Stratigraphic occurrence and localities: Solon Member, Linn Junction, Linn County, Iowa.
Discussion: Dr. James Scatterday of SUNY Geneseo, has examined this specimen as well as the holotype of *M. raripustulosus* (Walter, 1923) from the Cou Falls Member of the Coralville Formation, and in his opinion both specimens are conspecific with the type species, *M. pulchra. M. pulchra* is from a Devonian outlier, Calhoun County, Illinois that is considered to be a Solon equivalent, adding support that the pygidium from Linn County, belongs to that species. However, Dr. Scatterday was not aware of the fact that *M. raripustulosus* (SUI 9113) is from the Coralville Formation, significantly higher in the Devonian section; and that no Solon trilobites are known unquestionably above the Solon-Rapid contact. More and better quality material is needed to resolve this problem.

Family SCUTELLUIDAE R. and E. Richter, 1955
Genus *SCUTELLUM* Pusch, 1833
Type species: *Scutellum costatum* Pusch, 1833
Diagnosis: "Cephalon low lying to moderately convex; glabella moderately expanded forward. Preglabellar

depression very narrow or absent. Three pairs of lateral glabellar impressions, 1p imperfectly horseshoe shaped (convex inward) with a small medium elevation, 2p a gentle transversely oval depression separate from axial furrow, 3p deeper and longer than 2p typically reaching axial furrow. An additional area of muscle insertion is the semicircular depression in the fixed cheek adjacent to axial furrow and posterior to 1p impression. Anterior part of fixed cheek narrow, broad in vicinity of palpebral lobes. An eye ridge is typically present.

Thorax of ten segments, axis wide but narrower than pleurae. Pygidium semi- elliptical to slightly pentagonal. Raised central platform of pygidium fairly small, surrounding pygidial area concave in profile. Seven paired pleural ribs are broad and moderately convex, median rib wide and not bifurcated. Length of pygidial doublure about half of post-axial pygidial length" (Ormiston, 1967).

SCUTELLUM (SCUTELLUM) DEPRESSUM (Cooper and Cloud, 1938)

Figure 3, Number 2

Goldius thomasi? Walter, 1923, p. 282.

Scutellum tullium depressum Cooper and Cloud, 1938, p. 458, plate 55, figures 39-45.

Scutellum tullium depressum, Stumm, 1953, p. 128, plate V, figures 12,13.

Scutellum depressum Ormiston, 1967, p. 36-40, plate I, figures 1-6.

Holotype: U.S. National Museum 95201, Cedar Valley Formation?, Calhoun County, Illinois.

Description: "Outline of anterior margin of cranidium nearly straight medially. Preglabellar depression shallow and narrow. Glabella low convex, expanding rapidly anteriorly, as long as wide. Three pairs of glabellar furrows are indicated by shallow depressions. Occipital furrow broad and moderately deep. Occipital ring broad, convex. Palpebral lobes lower than glabella, longer than wide, possessing a tubercle in posterior portion. Entire surface of glabella tuberculate. Thorax with 10 segments. Pygidium a little over twice as wide as long, semi-elliptical in outline. Triangular axis convex, axial furrows very shallow. Pleural region bears 7 pairs of furrows and ribs, furrows do not reach margin. Ribs moderately convex, tapering anteriorly. Whole pygidium tuberculate" (see Ormiston, 1967 for complete description).

Stratigraphic occurrence and localities: Solon Member, Rock Island County, Illinois and Scott, Benton and Johnson counties, Iowa; Cedar Valley? outlier, Calhoun County, Illinois; Traverse Group, Petoskey Formation, Michigan; and Blue Fiord Formation, Brathurst Island, Canadian Arctic.

Discussion: Solon material consists of a complete pygidium (SUI 9084) from Turkey Creek, Johnson County, a perfect cranidium recently collected by Curt Klug (August, 1991) at Vinton, Iowa, and four pygidium fragments and a free cheek from Rock Island County. This wide ranging species is very similar to *S. tullium* (Hall, 1888) from the Tully Formation of New York, *S. flabelliferum* (Goldfuss, 1843) from Germany and the type species *S. costatum* from the Givetian and Frasnian of Europe. Cranidia of these species can be distinguished only with difficulty, but the pygidia are less alike (Ormiston, 1967).

S. depressum differs from *S. thomasi* (Walter, 1923) (SUI 9085, 9087) from the Owen Member of the Lime Creek Formation in being much larger in size, possessing a less coarsely tuberculate pygidium, and lacking an occipital spine.

Family PHACOPIDAE Hawle and Corda, 1847

Subfamily PHACOPINAE Hawle and Corda, 1847

Genus *PHACOPS* Emmrich, 1839

Type Species: *Calymene latifrons* Bronn, 1825

Diagnosis: "Vincular furrow continuous, rear edge sharp, higher than anterior; marginal ridge narrow, doublure concave. Hypostoma elongate, posterior margin with 3 denticles" (Moore, 1959).

PHACOPS IOWENSIS IOWENSIS Delo, 1935

Figure 3, Number 3

Phacops rana, Walter, 1923, p. 310-314, plate XXVI, figures 25,26?.

Phacops iowensis Delo, 1935, p. 422-423, plate 48.

Phacops iowensis, Stumm, 1953, p. 140-142, plate 12.

Phacops iowensis iowensis, Eldredge, 1972, p. 58-59, 92, figure 3.

Holotype: SUI 9266, Solon Member, Linn Junction, Linn County, Iowa.

Description: "Eyes moderately large, bearing 13 dorsoventral files of lenses in normal adults. Trace of facial suture over ocular platform deeply incised. Genal angles terminating in blundt point, recurved dorsally from ventral cephalic margin. Glabellar furrow 1p variably incised, occasionally obsolescent mesially. Glabellar furrows 2p and 3p weakly developed or absent. Cephalon covered by round, conical tubercles of uniform size. Thorax generally covered with tubercles similar to those on cephalon. Pygidium with 8-10 axial rings and 6-8 pleura. Pleura highly arched, pleural furrows deeply incised. Anterior 2-5 interpleural furrows frequently developed, with area of fused pleuron anterior to interpleural furrow more highly arched than posterior region. Tuberculation heavily developed over surface of pygidium, including pygidial axis" (Eldredge, 1972).

Measurements: Holotype, length of cephalon 10 mm, length of thorax 15.5 mm, length of pygidium 5.5 mm and width across genal angles 17 mm.

Stratigraphic occurrence and localities: Solon Member, Rock Island County, Illinois; Scott, Johnson and Linn counties, Iowa; Traverse Group, lower Petoskey Formation, Michigan.

Discussion: *P. iowensis iowensis* is second to *D. prouti* in abundance at most Solon localities, but sometimes dominates (e.g. Allied Quarry, Rock Island). It is distinguished from *P. rana norwoodensis*, which occurs commonly in the overlying Rapid Member, mainly by possessing an eye with fewer total facets (~40) and fewer doral-ventral files (13). *P. rana norwoodensis* averages 50 facets and 15 files. It also has a much more tuberculate dorsal exoskeleton. *P. iowensis iowensis* appears to be restricted to the Solon, whereas *P. rana norwoodensis* is similarly restricted to the Rapid Member. Eldredge (1972) questionably listed the occurrence *P. rana norwoodensis* in the Solon, but this record was based on "float" material.

Family DALMANITIDAE Vogdes, 1890
Subfamily ASTEROPYGINAE Delo, 1935
Genus *GREENOPS* Delo, 1935
Subgenus *NEOMETACANTHUS* Richter and Richter 1948

Type species: *Phacops stellifer* Burgmeister, 1843

Diagnosis: "Cephalon with palpebral lobes high above posterior part of glabella, adjacent region of fixigenae sloping steeply toward axial furrows. Thoracic pleural processes long, spinelike. Pygidium with fairly distinct border furrow and slightly inflated border that is visible between traversing pads; lateral and posterior processes of border slender" (Moore, 1959).

GREENOPS (*NEOMETACANTHUS*) N. SP.

Figure 3, Number 6

Asteropyge fitzpatricki? Walter, 1923, p. 310-311, plate XXVI, figures 19,20.

Greenops (Neometacanthus) fitzpatricki, Hickerson, 1989, p. 33, figure 2.3.

Description: General outline of cephalon like *G. stellifer* (see Moore, 1959, p. 480). Glabella with a broad frontal lobe. Lateral glabellar furrows deeply incised, 3p furrow directed posteriorly, other furrows directed anteriorly. Entire glabella coarsely tuberculate. Occipital furrow narrow, deeply incised. Palpebral lobes low convex, inclined axially and tuberculate, eyes elongate reniform, rising slightly above glabella. Genal spines long, wide, flat with a blundt termination, and covered with small tubercles. Thorax with 10 segments. Axis convex, pleurae depressed, terminating in long thoracic spines. Thorax not nearly as coarsely tuberculate as cephalon or pygidium. Pygidium with low convex axis composed of 10 or 11 rings. Axial segments ornamented with a row of small tubercles along posterior margins. Pleural field composed of 5 convex ribs with the anterior pleural bands separated from the posterior pleural bands by wide, deeply incised pleural furrows, interpleural furrows shallow. Posterior pleural bands elevated above anterior bands. Anterior pleural bands display rows of perforations (punctae?). Pygidial lappets long, narrow, very spinose. Axial spine long, narrow, triangular. Entire pygidium, including lappets is tuberculate.

Measurements: Length of cephalon 10 mm, length of thorax 13 mm, length of pygidium 10 mm and width across genal angles 21.5 mm.

Stratigraphic occurrence and localities: Solon Member, Rock Island County, Illinois and Scott and Linn counties, Iowa.

Discussion: This species will be named in honor of David Sivill who collected the finest specimen and kindly loaned it for study. It is similar to *G. (Neometacanthus) barrisi* (Hall, 1888) from the Rapid Member, differing mainly in being much larger in size, more coarsely tuberculate, more spinose and possessing a differently shaped axial spine. It is also similar to *G. traversensis* Stumm (1953) and *G. alpenensis* Stumm (1953) from the Traverse Group of Michigan. *G. traversensis* differs by possessing prominent, posteriorly directed axial spines on each segment of its thoracic axis. *G. alpenensis* is similar, possibly conspecific with *G. barrisi* and therefore differs from *G. (Neometacanthus)* n. sp. in the same characters as the former. The holotype pygidium of *G. fitzpatricki*

(SUI 9080) differs from this species by having much wider, flater pygidial lappets, a long uniformly tapering axial spine, lack of tuberculation, and has more inflated traversing pads. An enrolled specimen (SUI 9081) from Linn Junction, referred doubtfully to *G. fitzpatricki* by Walter (1923), is here included with this new species.

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APPENDIX I. Solon trilobite data base by locality. CO= complete outstretched exoskeleton, CE= complete and enrolled, MLT= moulted exoskeleton (i.e. moult ensemble or thoracopygidia), PR= partial remains (cephalothorax or fragmentary exoskeleton), SC= sclerite (cephalon, Cranidium, pygidium, librigena), TL= total specimens, PCT/TL= percentage of total specimens from that locality.

	CO	**CE**	**MLT**	**PR**	**SC**	**TL**	**PCT/TL**
Mill Creek Quarry, Milan, Illinois							
Dechenella prouti	00	01	01	00	07	09	60.0
P. iowensis iowensis	01	00	00	00	01	02	13.3
C. arietinus	00	00	00	00	02	02	13.3
D. cf. *haldemani*	00	00	00	01	00	00	06.7
unident. proetid	00	00	00	00	01	01	06.7
Allied Quarry, Rock Island, Illinois							
Dechenella prouti	01	00	00	00	00	01	09.1
P. iowensis iowensis	04	01	02	02	01	10	90.9
Mississippi River levee, Rock Island and Moline, Illinois							
Dechenella prouti	27	16	02	18	49	112	45.9
P. iowensis iowensis	02	26	01	17	21	67	27.5
C. arietinus	05	02	00	01	27	35	14.4
Neometacanthus n. sp.	02	03	03	05	08	21	08.6
D. cf. *haldemani*	00	00	01	00	02	03	01.2
Scutellum depressum	00	00	00	00	05	05	02.1
Cyphaspis sp.	00	00	01	00	00	01	00.4
Lake Macbride spillway, natural outcropping, Johnson Co., Iowa							
Dechenella prouti	03	00	00	00	06	09	36.0
P. iowensis iowensis?	00	01	02	00	01	04	16.0
C. arietinus	00	00	00	00	12	12	48.0

APPENDIX II. Solon trilobite body cluster data. TYPE=type of cluster, MONO=monospecific body cluster, MIXED=mixed species body cluster, SP. PRES.=species present in cluster, CO=complete outstretched specimens, CE=complete enrolled, PT=partial remains (cephalathoracic or thoracopygidia), SC=sclerites (cephala,pygidia,cranidia,librigenae), T=total number of specimens in cluster.

TYPE	SP. PRES	CO	CE	PT	SC	T
MONO	*D. prouti*	02	03	03	04	12
MONO	*D. prouti*	03	00	00	00	03
MONO	*D. prouti*	02	00	00	01	03
MONO	*D. prouti*	03	00	00	00	03
MONO	*D. prouti*	01	00	01	01	03
MONO	*D. prouti*	02	02	00	02	06
MONO	*P. iowensis*	02	01	02	00	05
MONO	*P. iowensis*	02	00	00	01	03
MONO	*P. iowensis*	00	01	03	02	06
MONO	*P. iowensis*	00	02	00	03	05
MONO	*G. (Neo.)* n.sp.	00	00	02	01	03
MONO	*G. (Neo.)* n.sp.	02	01	00	02	05
MONO	*G. (Neo.)* n.sp.	01	01	03	03	08
MIXED	*G. (Neo.)* n.sp.	02	00	00	00	
	C. arietinus	00	01	00	00	03
MIXED	*D. prouti*	01	00	00	00	
	P. iowensis	00	02	00	00	03
MIXED	*D. prouti*	02	03	03	07	
	P. iowensis	00	01	00	03	
	S. depressum	00	00	00	01	20
MIXED	*P. iowensis*	00	01	01	03	
	C. arietinus	00	00	00	01	05
MIXED	*G. (Neo.)* n.sp.	00	02	00	01	
	C. arietinus	00	00	00	02	05

DISTRIBUTION OF STROMATOPOROIDS IN THE IDLEWILD MEMBER OF THE LITHOGRAPH CITY FORMATION IN NORTH-CENTRAL IOWA

by

Melanie Smith Turner and Carl W. Stock
Department of Geology
University of Alabama
Tuscaloosa, Alabama 35487-0338

INTRODUCTION

Stromatoporoids are an extinct group of organisms believed by most paleontologists to belong to phylum Porifera. They appeared in the Early Ordovician, increased in abundance through the Middle Devonian, were greatly reduced in numbers in the middle of the Late Devonian (close of the Frasnian), and finally became extinct at the close of the Devonian. Stromatoporoids played an important role in the construction of Silurian and Devonian reefs.

Stromatoporoids have a calcareous exoskeleton which can have a variety of morphologies, ranging from laminar to hemispherical, bulbous, or branching. The more delicate branching forms (e.g., *Amphipora*) are thought to have lived in calm lagoonal environments, whereas the more robust forms are thought to have lived in higher energy environments. As such the exoskeleton has been used historically as an indicator of the paleoenvironment; however, there is some evidence to suggest that genetic controls may dictate the external shape (e.g., Kershaw, 1990). The most current treatment of the various aspects of stromatoporoid paleontology is found in the short course notes of Rigby and Stearn (1983). This volume discusses stromatoporoid gross morphology, microstructure, diagenesis, classification, biological relationships, paleoecology, and evolution. Some of the more recent thoughts on the biological affinities of stromatoporoids have been presented by Wood (1990).

In north-central Iowa stromatoporoids form biostromes at many places in the Upper Devonian (early Frasnian age) Idlewild Member of the Lithograph City Formation, which is known from outcrops in Mitchell, Floyd, Butler, and Black Hawk Counties. Stromatoporoids collected for this study were taken from the following quarries: Duenow, Lithograph City, Floyd North, Hanneman, Clarksville, and Yokum (Fig. 1). Eighteen species representing 13 genera have been identified from the Idlewild Member.

PREVIOUS WORK

Nearly all of the previous publications on stromatoporoids from Iowa have dealt with stratigraphic units found above the Lithograph City Formation, which are regarded as Late Devonian in age. Hall and Whitfield (1873), in the first publication on Upper Devonian stromatoporoids of North America, described four new species. Stock (1984a) redescribed and reinterpreted these species, lowering the number to three: *Actinostroma expansum* from the Shell Rock Formation, and *Stromatopora incrustans* and *Clathrocoilona solidula* from the Lime Creek Formation. A fifth species named by Hall and Whitfield, *Stromatopora erratica*, from Middle Devonian rocks at Waterloo, Iowa, was not illustrated, and has no known type specimen. Parks (1936) added two more species: *Trupetostroma iowense* from the Shell Rock Formation, and *Stromatoporella kayi* from the Lime Creek Formation. The first is actually a species of *Hermatostroma*, and the second a species of *Stictostroma*.

The stromatoporoid fauna of the Mason City Member of the Shell Rock Formation, the next youngest formation above the Lithograph City, was described in detail by Stock (1982) who described 11 species, two of them new. A general overview of stromatoporoid occurrences in the Shell Rock and Lime Creek Formations was presented by Stock (1984b).

STROMATOPOROID BIOSTRATIGRAPHY

In north-central Iowa the Lithograph City Formation is divided into three members: the lower Osage Springs Member, the Thunder Woman Shale Member, and the upper Idlewild Member. Stromatoporoid biostromes are common in the Osage Springs and Idlewild Members; however, in the present study only the

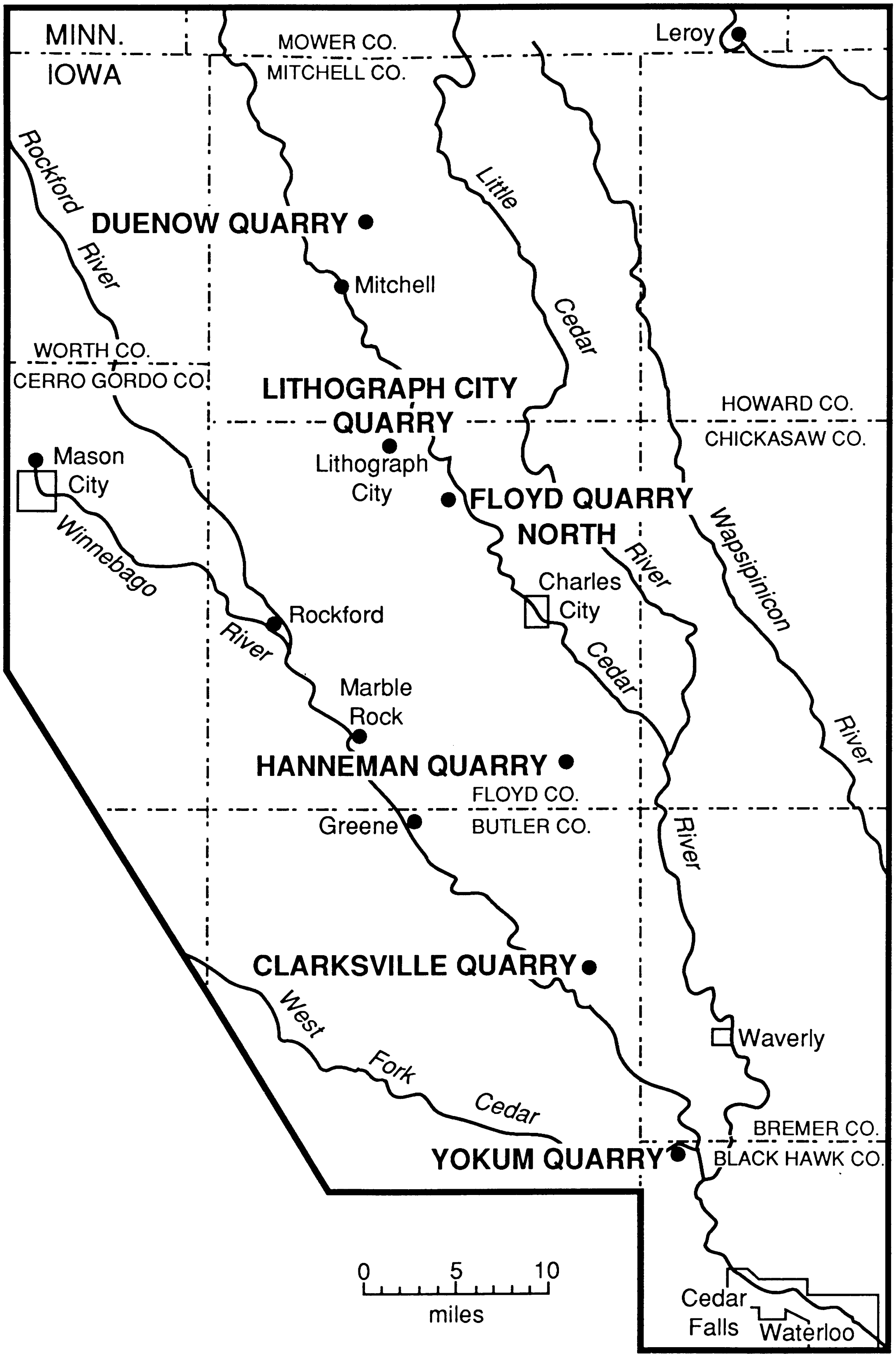

Figure 1. Index map of the field area showing the location of the six quarries sampled for this study.

Idlewild Member was sampled.

The Idlewild Member stromatoporoid occurrences were described by Bunker, Witzke, and Day (1986), who noted two stromatoporoid biostromes within the Member at the Yokum Quarry, and we found two at the Duenow Quarry. Both biostromes at Duenow were sampled, but only the upper biostrome at Yokum was sampled.

Duenow Quarry—SE1/4, sec. 8, T99N, R17W, Mitchell County.
 Upper Unit:
  Actinostroma clathratum Nicholson
  Hermatostroma insulatum Birkhead
  Hammatostroma albertense Stearn
  Clathrocoilona abeona Yavorsky
  Stachyodes cf. *S. costulata* Lecompte
 Lower Unit:
  Atelodictyon strictum Lecompte
  Trupetostroma bassleri Lecompte
  Pseudoactinodictyon bullulosum Stearn

Lithograph City Quarry—SW1/4, NE1/4, sec. 26, T97N, R17W, Floyd County.
  Atelodictyon strictum Stearn
  Stictostroma maclareni Stearn
  Clathrocoilona abeona Yavorsky

Floyd Quarry North—SW1/4, SW1/4, SE1/4, sec. 9, T96N, R16W, Floyd County.
  Atelodictyon stelliferum Stearn
  Trupetostroma bassleri Lecompte
  Parallelopora catenaria Birkhead
  Pseudoactinodictyon bullulosum Stearn
  Trupetostroma hayense Stearn
  Bullulodictyon patokense Yavorsky

Hanneman Quarry—NE1/4, NE1/4, sec. 20, T94, R15W, Floyd County.
  Trupetostroma bassleri Lecompte
  Trupetostroma hayense Stearn
  Trupetostroma saintjeani Stearn
  Clathrocoilona abeona Yavorsky
  Habrostroma turbinatum (Birkhead)

Clarksville Quarry—SW1/4, NE1/4, sec. 16, T92N, R15W, Butler County.
  Atelodictyon strictum Lecompte
  Atelodictyon cf. *A. fallax* Lecompte
  Trupetostroma hayense Stearn
  Stictostroma maclareni Stearn
  Pseudoactinodictyon bullulosum Stearn

Yokum Quarry—NW1/4, SW1/4, sec. 4, T90N, R14W, Black Hawk County.
  Trupetostroma hayense Stearn
  Trupetostroma saintjeani Stearn
  ?Ferestromatopora dartingtonensis (Carter)
  Stachyodes spongiosa Stearn

Correlation

The reader should be aware that species identifications noted below are tentative in nature, representing work in progress; however, we have confidence in a large majority of our identifications.

Within Iowa.—Four of the species identified from the Idlewild Member also occur in the younger Mason City Member of the Shell Rock Formation in north-central Iowa: *Actinostroma clathratum*, *Hammatostroma albertense*, *Trupetostroma bassleri*, and *T. hayense*.

Two specimens provided by Jed Day from the Andalusia Member of the Lithograph City Formation at the Buffalo Quarry in Scott County, east-central Iowa proved not to be conspecific with those from the Idlewild Member. One is a thin laminar specimen of an undetermined species of *Stictostroma*, and the other is a poorly preserved laminar specimen of what may be *Coenostroma*, that resembles "*Syringostroma*" *astrorhizoides* Birkhead from Missouri.

Outside Iowa.—Six of the Idlewild Member stromatoporoid species are also known from the Middle Devonian (upper Givetian) Callaway Formation of Missouri: *Trupetostroma hayense* (as *T. ideale*), *Hermatostroma insulata*, *Habrostroma turbinata*, *?Ferestromatopora dartingtonensis*, *Parallelopora catenaria*, and *Stachyodes spongiosa*. Western Canada has yielded many of the same species as the Idlewild. *Hammatostroma albertense*, *Stictostroma maclareni*, and *Pseudoactinodictyon bullulosum* are know exclusively from Frasnian strata, *Actinostroma clathratum*, *Atelodictyon stelliferum*, *Ferestromatopora dartingtonensis* (as *Parallelopora ponomarevi*), and *Stachyodes spongiosa* occur in both Frasnian and Givetian rocks, and *Clathrocoilona abeona* has been found in Givetian units only. At least nine of the Idlewild stromatoporoid species can be found on other continents, including Europe, Asia, and Australia. Their occurrences there represent either Middle or Late Devonian age deposits.

Summary. The stromatoporoids identified from the Idlewild Member do little to help clarify the position of the Middle-Upper Devonian boundary in Iowa. Occurrences of these species elsewhere are in Givetian and/or Frasnian age strata. It is clear that during the time these stromatoporoids lived, they experienced a high degree of cosmopolitanism.

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A DEVONIAN PAPER COAL (CUTINITE) IN THE LITHOGRAPH CITY FORMATION AT GARRISON, IOWA

by

Curtis R. Klug and Jeffry T. Schabilion
Department of Geology and Department of Botany
The University of Iowa
Iowa City, Iowa 52242

INTRODUCTION

The quarry at Garrison (N1/2, NE1/4, sec. 33, T85N, R11W, Benton County, Iowa; Fig. 1) is of interest in that it occurs approximately at the boundary between the southern and northern facies tracts of the Iowa Devonian outcrop belt. Because of this unique geographic location, lithostratigraphic relationships not observable elsewhere in the state can be examined in this quarry. In addition, the varied sedimentary textures and structures exposed within the quarry represent an unusual suite of depositional environments. Of particular interest is the localized occurrence of a thin coal in the southern part of the quarry. The presence of this coal was noted in 1984 by B. J. Bunker and B. J. Witzke, of the Iowa Geological Survey Bureau, who provided one of the authors (CRK) with a sample to process for spores. It was during the processing of this sample that the coal was found to consist almost entirely of plant cuticle. Cuticle-rich coals are generally referred to as cutinites or paper coals, the latter term in reference to their tendency to peel off in thin layers, especially when weathered.

Cuticle is the resistant, waxy or fatty layer found on the outer walls of epidermal cells of a variety of plants. It is rather impervious to water and serves, in most plants, to reduce the amount of water lost to the atmosphere through evaporation. Consequently, it tends to be best developed on the subaerially exposed portions of terrestrial vascular plants, particularly those of arid environments. While the cuticle reduces the loss of water by evaporation, it also inhibits the exchange of the gases necessary to carry on the photosynthetic processes. This difficulty is overcome by the development of small pores (stomata) in the cuticles of the subaerial portions of most vascular plants. The stomata can be opened or closed by means of guard cells that border the stomata. The nature of the guard cells and stomata are often distinctive, and can be of taxonomic value. While the cuticle, in itself, is not cellular in structure, the outlines and arrangements of the underlying epidermal cells are often preserved on the inner surfaces of the cuticle. Although the stomata are characteristic of the subaerially exposed portions of vascular plants, they may be absent or rare on immersed leaves or on the undersurfaces of floating leaves of aquatic plants. Cuticle may also be relatively thick in plants of paralic environments, particularly those exposed to alternating saline and fresh waters.

OTHER REPORTS OF COALS AND PLANT FOSSILS IN THE DEVONIAN OF IOWA

The coal at Garrison is the only known occurrence of a cutinite, or paper coal, in the Devonian of Iowa, however, other thin coals have been reported from a number of Devonian localities in the state. According to Dow (1960), Owen first reported on the occurrence of a coal in the Devonian of Johnson County, Iowa in 1899. This coal, which is exposed on the campus of the University of Iowa in Iowa City, was later examined in greater detail by Dow (1960) and interpreted to be a cannel coal, that is, one dominated by spore exines. This coal was reexamined during a palynological investigation by Sanders (1968) who found that it contained a large percentage of spores that he interpreted to be algal in origin as well as trilete miospores, and concluded that the coal would be better referred to as a marine boghead coal. Zawistowski (1991, pers. comm.) reports having found a "thin bituminous (coal?) located approximately 38' below the Rapid/Coralville contact in the northwest and the northeast highwalls of the Garrison Quarry" in 1971, but did not find any plant macrofossils. He also noted "a thin (0.2') coaly shale bed" in the Pint's Quarry, which he believes may be a cuticle coal. The authors of the present paper have not

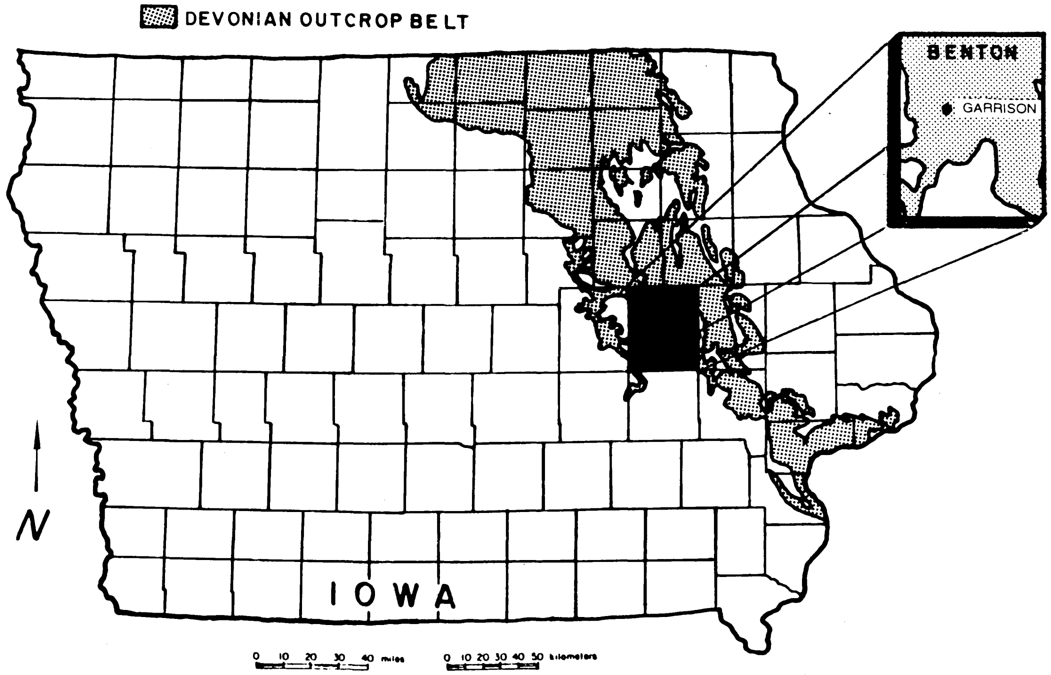

Figure 1. Map of Iowa showing the location of Garrison and the Devonian outcrop belt (modified from Witzke, Bunker, and Rogers, 1989).

had the opportunity to relocate these coals.

In addition to the novelty of a paper coal in Iowa, the Garrison coal and the immediately adjacent deposits are of interest for their plant macrofossil content. Plant macrofossils are extremely rare in the Devonian of Iowa, and have been reported from only a few localities. Udden (1898) reported the occurrence of the presumed plant remains *Spirophyton* from the Cedar Valley strata of Muscatine County, Iowa. The affinities of *Spirophyton* are somewhat uncertain, but the genus is now generally considered synonymous with the feeding burrows referred to as *Zoophycos*. Zawistowski (1971, p. 38) reported psilophyte remains from an argillaceous calcilutite he referred to as the "key bed" from the Rapid Member of the Little Cedar Formation. This reported occurrence has not been verified as his collections have not been located, and attempts to recover additional plant macrofossils from this horizon have been unsuccessful. Plant macrofossils have also been reported by Heyo Van Iten from a section in Fayette County, Iowa. He has interpreted his specimens to be the remains of siphonous green algae (1991, Van Iten, pers. comm.). One of the authors of the present paper (CRK) visited the Fayette locality and recovered a single plant fossil. The specimen possesses a single dichotomous branch, small spines or enations and may have a vascular strand, suggesting affinities with the psilophytes. Somewhat lower in the Devonian section of Illinois, across the Mississippi River approximately five miles from Iowa, William Hickerson recovered carbonaceous remains on bedding surfaces of the Spring Grove Member of the Pinicon Ridge Formation. These have yet to be described and their biologic affinities determined, but at least some appear to be plant remains.

PROCESSING TECHNIQUES

Cuticular material was freed from samples of the paper coal by maceration in common household bleach. Initially, the coal samples, which were approximately 1 cm thick, were immersed in the bleach for approximately 72 hours. After this time, the samples were removed and placed in another container where they were washed with running water. Samples of cuticle freed in this manner were then sieved to separate the coarser cuticular pieces from the material less than about 2 mm in diameter. The remaining coal was then placed back into the bleach and, after about 24 hours, was washed again. This process was repeated until the entire piece of coal had been macerated. The larger pieces of cuticle were examined for morphologic characteristics. The finer fraction was generally discarded, although some of this material was saved to be examined for palynomorph content. Most of the freed cuticle was stored in water, but some pieces were dehydrated in denatured ethanol and then mounted in Canada balsam on glass slides to be examined microscopically. Specimens of cuticle were examined and photographed under interference contrast lighting with a Leitz/Wetzlar Dialux microscope.

Cuticle was also recovered from the shale underlying the coal by soaking the dried shale in Stoddard's Solvent for 24 hours. The Stoddard's Solvent was then poured off and the sample covered with water. This very effectively dispersed the shale and freed the cuticle. Cuticle recovered in this fashion was very dark brown in color and difficult to examine with transmitted light. Presumably these cuticle samples could be lightened up by treatment with bleach, but since there was no apparent difference between the cuticle obtained from the shale and that of the coal and, as abundant material had been recovered from the coal, no effort was made to follow up on this possibility.

Additionally, a ground thin-section was made of the fresh coal and examined microsopically in the same manner as the cuticular fragments. The specimens described and illustrated in this paper are reposited in the fossil collections of the Geology Department of the University of Iowa.

NATURE OF THE CUTICLE AND THE PAPER COAL

The Garrison paper coal is composed primarily of the cuticle of what appears to be a very low diversity, perhaps monospecific, flora. The material recovered to date apparently represents the cuticular layers of simple axes typically about 2 to 5 mm in diameter. While segments of cuticle up to 85 mm in length have been recovered (Plate 1, Fig. 1), none of these show any evidence of branching and only a few specimens appear to preserve the terminations of the axes. The cuticle itself is typically 1.5 to 5.5 mm thick and is, for the most part, evenly thick around the perimeter at any point along the length of the axis. Distinct outlines of epidermal cells are present on the inner surfaces of most pieces of the cuticle (Plate 2, Fig. 2). These cells are somewhat variable in shape, but tend to be elongate straight-sided polygons that average about 50 mm by 125 mm. To date, no evidence of stomata or the accompanying guard cells has been recognized. Many of the cuticle fragments, however, possess scattered circular to subcircular pores, generally on the order of 200 to 300 mm in diameter (Plate 1, Fig. 4). Some of these pores are surrounded by a ring of smaller, nearly equant cells of about 40 to 50 mm in diameter. Many of these pores appear to be smooth sided around only half of the perimeter, the other half appearing slightly tattered, but retaining the circular outline (Plate 1, Fig. 5). The smooth half of these frequently appears to have a thicker margin and may be drawn out to form a short, hood-like projection (Plate 1, Fig. 6). Also recovered from the Iowa cutinite are specimens that possess simple spines or enations that are truncated and open at their distal ends (Plate 1, Figs. 2 & 3). These spines may be up to .6 mm in lenth but, in general, are considerably smaller. Pores, like those of the nonspinose fragments, also occur in the spinose cuticular material.

Occasionally, circular (originally spherical?) features have been noted, and it appears that at least some of these represent sporangial structures. In at least one case, (Plate 2, Fig. 3), a concentration of thin-walled spores was found at the base of a spherical structure but, surprisingly enough, not clearly within the structure itself. This sporangial? structure is located in a lateral position and does not appear stalked, but rather is appressed to the main axis. Distinct trilete marks are present on some of the spores (Plate 2, Fig. 6), but are indistinct or absent from many others. It may be that the spores are immature and the spore walls incompletely developed, or the overlapping of the spores may be obscuring the trilete marks. Spores also occur scattered throughout the cutinite, but appear to have been fortuitously trapped within the layers of cuticle during deposition, as several different spore types have been observed within a single piece of cuticle, and they do not occur concentrated in masses like those described above.

POSSIBLE BIOLOGICAL AFFINITIES OF THE PLANT REMAINS FROM GARRISON

The biologic affinities of the plants that produced the cuticle recovered from the paper coal at the Garrison Quarry remain uncertain. Cuticle or cuticle-like structures occur in a variety of plant types, including nonvascular plants such as some algae (e.g. *Fucus*) and some bryophytes. The Devonian form, *Foerstia* (?*Protosalvinia*), consists of bilobed thalloid structures

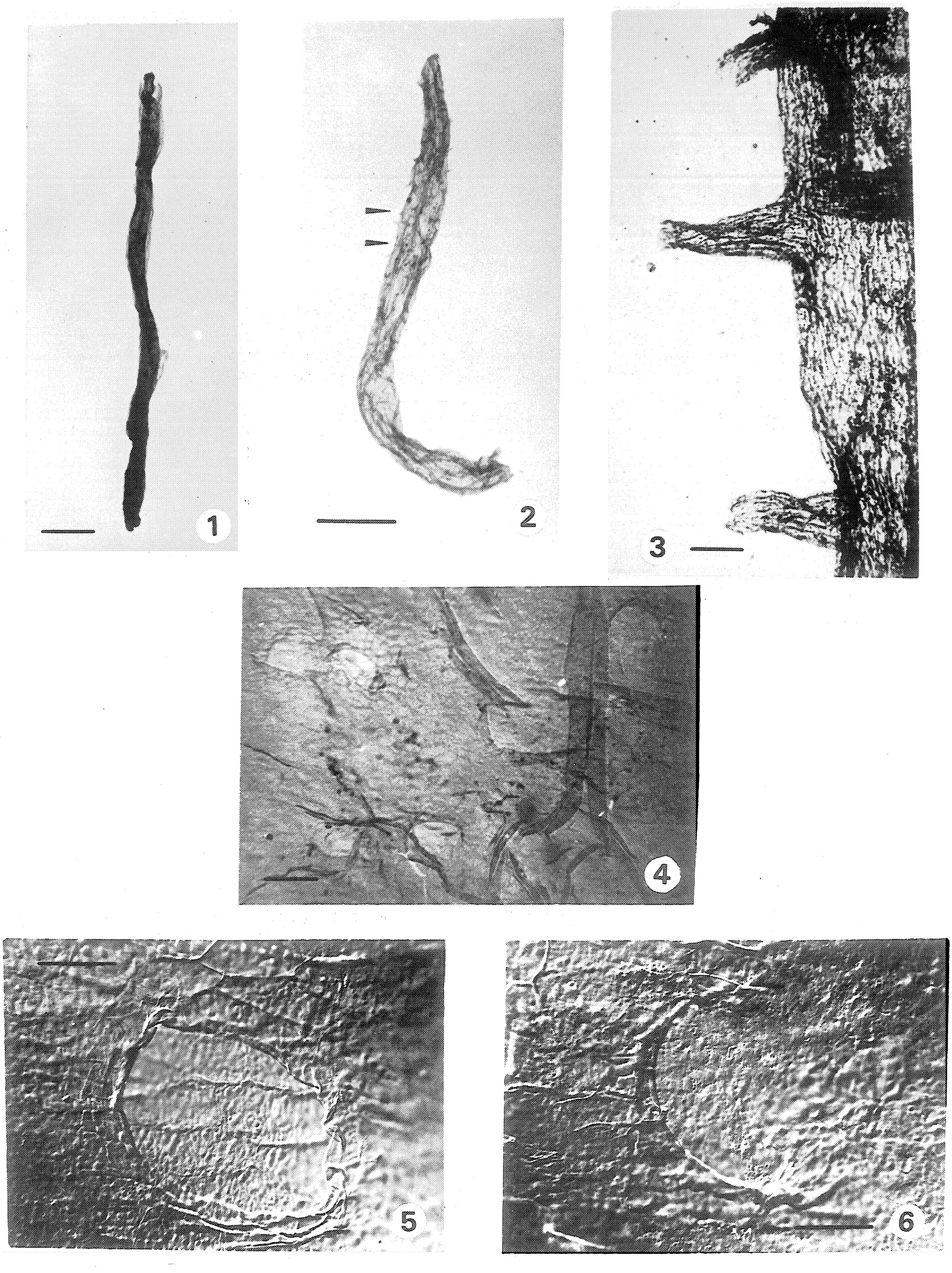
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Plate 1. Specimens and structures of the cuticle from the paper coal at Garrison, Iowa.

Figure 1. Longest specimen of cuticle recovered so far from the paper coal. This specimen lacks spines and appears to be terminated. Specimen is illustrated at approximately natural size; scale bar = 10 mm.

Figure 2. Specimen of cuticle bearing numerous spines. Detail of margin of cuticle segment between arrows shown in Fig. 3. Approximately X1.5; scale bar = 10 mm.

Figure 3. Enlargement of the cuticle margin between arrows in Fig. 2 showing detail of open-ended, truncated spines. Approximately X40; scale bar = 250 mm.

Figure 4. Cuticle specimen with numerous pores, most of which appear "hooded". Approximately X 40; scale bar = 250 mm.

Figure 5. Detail of a pore from the same piece of cuticle as that illustrated in Fig. 4. Specimen shows smooth margin that appears thicker around one-half of the pore and thinner around the other half. Specimen also shows papillose surface. Approximately X150; scale bar = 100 mm.

Figure 6. Detail of "hooded" pore from the same piece of cuticle as that illustrated in Figure 4. Approximately X150; scale bar = 100 mm.

thought to be the cutinized tips of pelagic algae (Schopf and Schweitering, 1970). The actual biologic placement of this genus, however, is somewhat uncertain. In any case, the rounded, bilobed terminations characteristic of *Foerstia* (?*Protosalvinia*) and the more rounded cellular outlines in the "cuticle" of this genus and in the meristoderm of brown algae (such as *Fucus*), suggest that affinities of the Iowa Devonian cuticle with the algae is unlikely.

Chaloner, Mensah, and Crane (1974) reported on the occurrence of two species of the non-vascular land plants, *Spongiophyton*, from the ?Middle Devonian of Ghana. Their specimens are thalloid, dichotomously branched and characterized by thick cuticle perforated by more or less irregularly distributed pores 200 - 300 µm in diameter. The pores occur only on the "upper" surface, which has a relatively thick cuticle, while the "lower" surface is characterized by thinner cuticle lacking pores. As commonly occurs in the Iowa Devonian cuticle, the pores of the Ghana specimens are surrounded by smaller, more equant cells than those found in the remainder of the cuticle. Chaloner, Mensah, and Crane (1974) report that there are never large pore-free areas on the pore-bearing surface of the Ghana material. Some of the Iowa specimens, however, show no pores whatsoever. The thickness of the cuticle of *Spongiophyton nanum* from Ghana ranges from 24 to 80 µm, with a poral to aporal thickness ratio of 2:1 to 3:1. In the Iowa material, the thickness is 1.5 to 5.5 µm, and shows no "poral" and "aporal" differentiation. Although superficially similar to *Spongiophyton nanum*, the difference in detail between the Iowan and Ghanan material implies that these forms are distinct.

Another group of fossil plants with which the Iowa specimens may have affinities are the Psilophytes. Pores have also been noted in the Lower Devonian plant remains from Wyoming identified by Dorf (1934) as *Psilophyton wyomingense*. He interpreted these "irregularly disposed areoles or scars" to represent the basal attachments of spines. In the specimens from the Iowa Devonian, however, no evidence has been noted to suggest that the pores represent physically removed spines. Unless there was a zone of dehiscence at the bases of the spines, one would expect the margins of the pores to appear more torn and less regular. Similiarly, the truncated ends of the spines would be expected to be more tattered than they are. One would also expect to see a range of spines from those in which only a small part was broken off to those that are completely missing. Such does not appear to be the case in the material at hand. The truncated spines of the Iowa material bear some similarity to those noted in specimens of *Psilophyton princeps* from the Gaspe and New Brunswick, Canada by Hueber (1967).

Cuticle preserving cell outlines similar to that of the Iowa material has been illustrated by Gensel and Andrews (1984, fig. 4.48A) from the zosterophyll *Sawdonia.* They also note the presence of papillae on the surfaces of the cells of some of the zosterophylls, a feature apparently in common with some of the Iowa

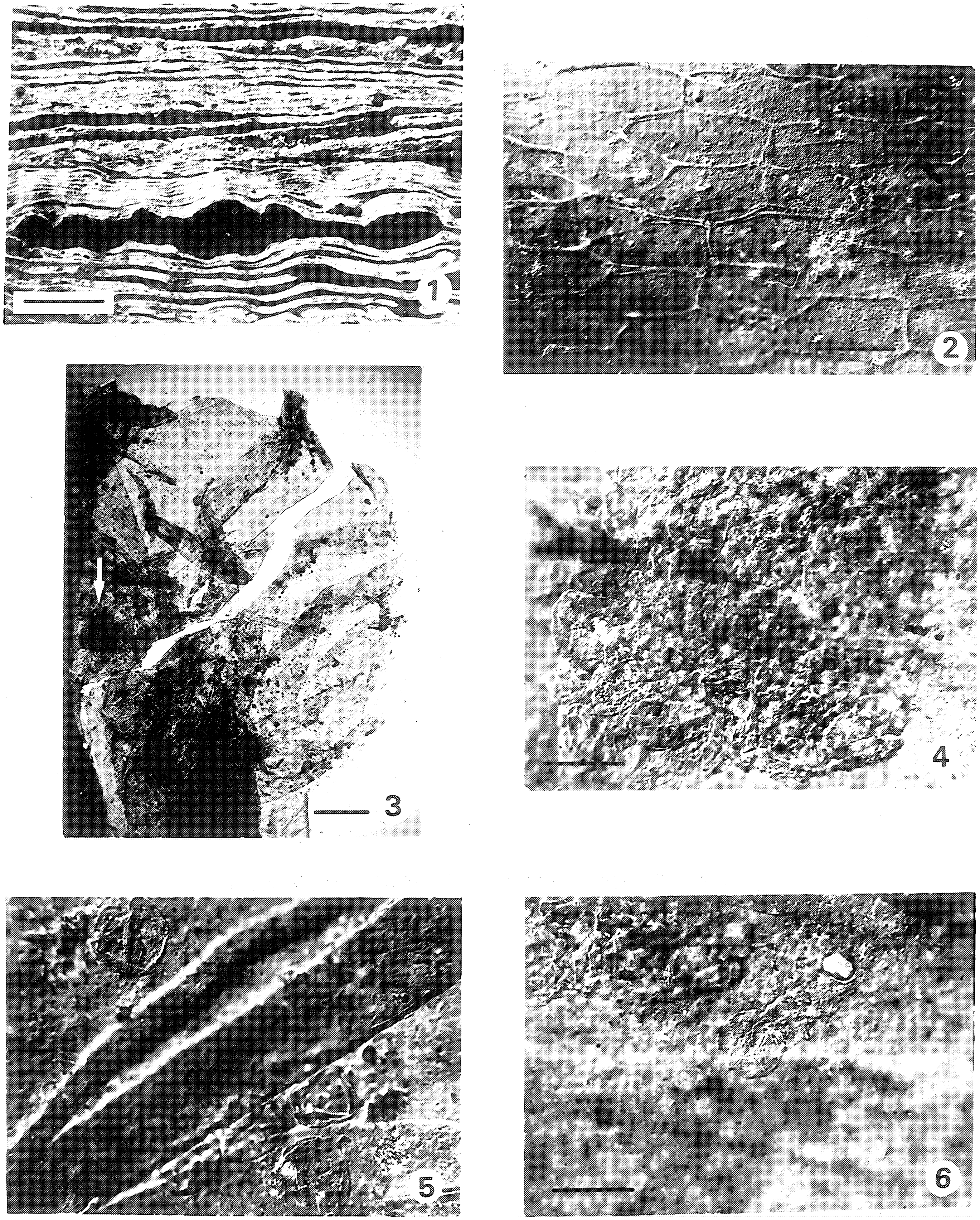
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Plate 2. Illustrations of paper coal, cuticle, and spores from the quarry at Garrison.

Figure 1. Ground thin-section of the Garrison paper coal showing alternating layers of light-colored cuticle and dark amorphous organic (humic?) material. Approximately X150; scale bar = 100 mm.

Figure 2. Cuticle showing distinct outlines of elongate cells typical of Iowa Devonian cuticle. Approximately X150; scale bar = 100 mm.

Figure 3. Circular sporangial? structure along margin of cuticle specimen. Arrow shows location of miospore mass. Approximately X 25; scale bar = 400 mm.

Figure 4. Mass of miospores at base of sporangial? structure from cuticle fragment of Fig. 3 (location of spore mass shown by arrow in that figure). Approximately X300; scale bar = 50 mm.

Figure 5. Somewhat scattered miospores from cuticle sample of Fig. 3. Approximately X300; scale bar = 50 mm.

Figure 6. Miospore from cuticle of Fig. 3 showing well-developed trilete mark. Figure also shows quartz silt grain to upper right of spore. Approximately X300; scale bar = 50 mm.

cuticle (Plate 1, Fig. 5). It is not entirely clear, however, whether the papillae in the Iowa material are primary structures, or are the result of partial degredation of the cuticle. Stomata have been reported in the zosterophylls (Gensel and Andrews, 1984, p. 80), but tend to be unevenly distributed, and are most abundant on the erect branches. The spines or enations found on some of the specimens from the Iowa Devonian also bear a resemblance to those reported from some of the zosterophylls, such as *Sawdonia acanthotheca.* The sporangia of some of the zosterophylls are similar in shape to the possible sporangial structures from the Iowa cutinite. Furthermore, the zosterophylls are characterized by laterally borne sporangia, again similar to that of the Iowa material. To the authors' knowledge, the relatively large pores so characteristic of the Iowa cuticular material have not been reported from the zosterophylls. While an affinity of the Iowa Devonian material with the zosterophylls or other psilophytes cannot at present be concluded with certainty, the possibility remains open.

GEOLOGIC SETTING OF THE PAPER COAL AND ADJACENT STRATA

The main paper coal at Garrison (Fig. 2) occurs as a very localized lens up to 4 cm thick and about 8 m wide in the southeastern part of the quarry. It lies about 2.7 m above the surface of the second bench from the top of the quarry. Another much thinner and less continuous cutinite layer occurs further west in the quarry along the southern wall at apparently the same stratigraphic position. Whether these two occurrences represent a once continuous deposit or two isolated cuticle rich pockets is unclear.

The coal is flanked immediately above and below by thin shales in a section otherwise dominated by limestones and dolostones. The following is a brief description of the strata that occur in that part of the section in which the coal is exposed. To facilitate discussion, the units are numbered from the base up. A more complete description of the entire section exposed in the quarry at Garrison can be found elsewhere in this guidebook.

Unit 1. The lowest part of the section exposed in the immediate vicinity of the coal is a mottled bluish-gray and light olive-gray wackestone at the base but becomes a packstone in the upper part, with grains ranging from coarse-sand to granule size. The unit is poorly fossiliferous, but does contain some massive stromatoporoids (to 15+ cm in diameter) and rare gastropods. The thickness of this unit is unknown, as the base of the unit is covered by talus.

Unit 2. Overlying unit 1, is a light yellowish-gray grainstone to packstone characterized by the presence of the articulate brachiopods *Athyris vittata* and *Independatrypa scutiformis* (Day, pers. comm., 1991). Gastropods and massive stromatoporoids are also abundant. The unit, which is approximately 87 cm

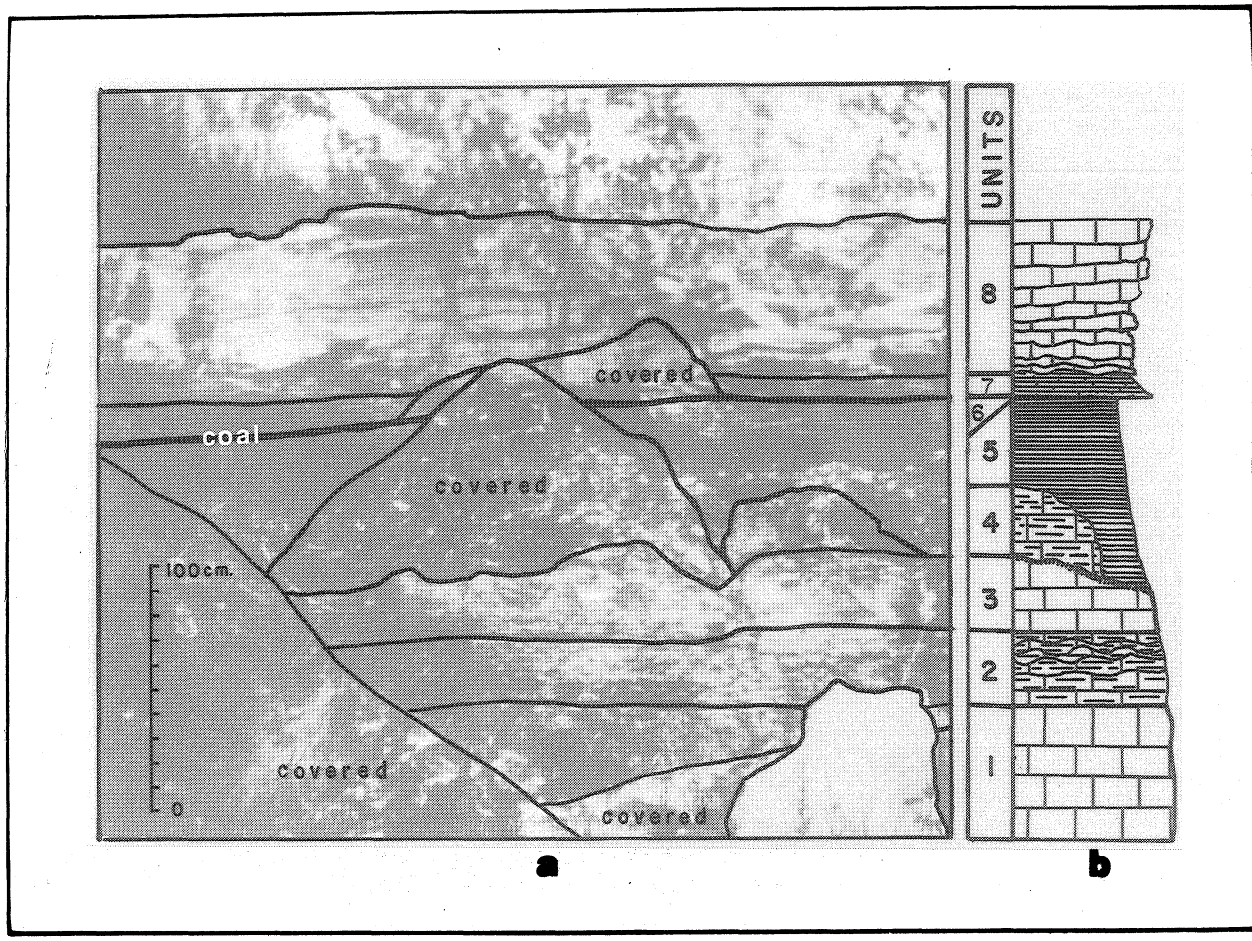

Figure 2. Portion of the section in the quarry at Garrison in which the paper coal occurs.
a. Highwall in southeastern part of quarry showing position of paper coal relative to adjacent strata.
b. Schematic of section shown in Figure 2a, showing position of coal (unit 6), lithologic units, and stratigraphic relationships of beds. Scale same as in Figure 2a.

thick, is slightly argillaceous in the lower 52 cm, but becomes more argillaceous in the upper 35 cm. The upper part is also wavy bedded and appears almost nodular.

Unit 3. Unit 2 grades into another grainstone to packstone that varies from light yellowish-gray in the lower part to medium bluish-gray in the upper part. Grains are coarse sand-sized and appear to be composed primarily of fossil debris. The unit is 27 cm thick, and is capped by a discontinuity surface along which is developed a pyritic rhind.

Unit 4. The discontinuity surface is generally overlain by a greenish-gray shale. Very locally, however, a light bluish-gray argillaceous, laminated wackestone to packstone occurs between the discontinuity surface and the shale. This limestone is abundantly fossiliferous, including encrusting and digitate stromatoporoids as well as articulate brachiopods, and is up to 30 cm thick.

Unit 5. The greenish-gray shale is, at best, only very slightly calcitic and, with the exception of a thin iron-stained zone about 7 cm below the top, appears quite homogeneous in composition. It is variable in thickness, but is up to 40 cm thick in the vicinity of the coal. With the exception of abundant cuticle, and a low abundance, low diversity miospore flora, this unit is apparently nonfossiliferous. The cuticle, however, is not developed into a coal and, in this respect, appears similar to the cuticle horizon on the south wall. A 500 g sample of the shale processed for miospores produced only about a dozen specimens. No other palynomorphs or microfossils, such as acritarchs, conodonts, or scolecodonts were noted.

Unit 6. Overlying the greenish-gray shale is the paper coal. As noted above, the coal itself has a maximum thickness of only about 4 cm, and thins rapidly to the north and the south. Furthermore, the strata at the level of the coal dip to the north and south, and are soon obscured by talus along the wall. The coal is dark grayish-brown in color, and has a dull luster, although, on cut and polished surfaces, it is seen to consist of thin dull bands alternating with brighter bands. In thin section (Plate 2, Fig. 1), it is seen to consist almost entirely of amber colored layers of cuticle, separated by thin bands or lenses of darker brown, amorphous organic (humic?) material. On weathered bedding surfaces, or surfaces that have been partially macerated in the lab., the long axes of the pieces of cuticle appear to be oriented nearly parallel to one another. In addition, on partially macerated surfaces of the coal, the pieces of cuticle appear to be somewhat interwoven. This interweaving of the cuticle, however, does not form a completely tangled mat, but rather forms a kind of fabric in which most of the cuticular pieces appear attached on one end, from which trails a length of free cuticle. The relative positions of the attached and free ends of the cuticular pieces does not appear to be random, but instead the attached ends tend to be toward one side of the cuticles pieces while the free ends trail off in the opposite direction, overlapping somewhat like the hairs of a pelt. Mineral constituents appear to be minor. Pyrite, however, is relatively abundant occurring as silt-sized grains to sand-sized framboids disseminated throughout the coal. Quartz silt is also found throughout the coal, but is a very minor component. Clays also appear to be a minor component throughout most of the coal, but may be more abundant locally as, for example, at the upper and lower surfaces of the coal. Occasional borings/burrows filled with clays, quartz silt, and even some carbonate grains have been noted in the coal. Volumetrically, however, these sediment-filled borings/ burrows represent a very minor component of the coal.

Unit 7. Overlying the coal is a thin grayish-brown shale. This shale contains numerous medium- to coarse- sand sized carbonate grains, most of which are rock fragments, but include some fossil fragments. Also present are some small cuticle fragments, but not nearly in the abundance of the coal or the underlying shale. In addition to the cuticle, fish fragments and carbonized plant remains are commonly encountered. A 2 gram sample of this shale produced an extremely abundant spore flora including both trilete miospores and megaspores, but no apparently marine forms such as acritarchs or scolecodonts.

Unit 8. The uppermost unit considered in this paper is light yellowish-gray to medium-gray and alternates between calcilutite and calcarenite. It is wavy laminated to thin-bedded and, in part, ripple marked. The lime muds associated with the ripples also show the development of what appear to be mudcracks. This unit is poorly fossiliferous, but does contain fish remains that appear identical to those recovered from the underlying shale.

DEPOSITIONAL ENVIRONMENTS OF THE GARRISON COAL AND ADJACENT STRATA

The limestone (unit 1) exposed at the base of the wall in which the paper coal is exposed possesses a very low diversity fauna implying that environmental conditions must have been hostile to most organisms. The range in texture from calcilutite at the base to calcarenite at the top suggests a change from quiet water to more aggitated conditions. The light color of the sediment suggests that the waters in which deposition occurred were well oxygenated. A paralic environment, in which salinities or temperatures fluctuated between extremes, would be consistent with the above observations. A shift from an initial supratidal setting above effective wave base to a slightly deeper wave-washed environment is suggested.

Unit 1 grades into the grainstones of unit 2. The higher diversity and abundance of fossils in unit 2 suggests continued deepening, into a more normal marine shallow subtidal to intertidal setting.

The grainstones to packstones of unit 3 are similar to those of unit 2, except that the fossils in unit 3 appear to be represented only by very fragmentary, sand-sized particles. A relatively shallower, higher wave energy environment, such as a beach, is suggested. The discontinuity surface at the top of this unit suggests that deposition was followed by a period of, perhaps subaerial, erosion.

The moderately developed fauna of unit 4 suggests that the depositional environment may have been similar to that of unit 2. The limestone overlying the discontinuity surface is, as noted above, of very local occurrence, and lies in unconformable contact with the overlying shale.

The greenish-gray clays of unit 5 immediately underlie the paper coal. The very low carbonate content of this unit suggests deposition under conditions considerably different from those of the carbonate-dominated marginal marine settings interpreted for much of the rest of the section. The relatively reduced state of the iron in this clay, as well as the lack of any textural or structural features to suggest soil development, implies deposition primarily in an aquatic environment. The apparent lack of stomata in the cuticle also suggests deposition under subaqueous conditions. The presence of the cuticle, if it has not been transported a great distance to the depositional site, suggests that the waters must have been relatively shallow, particularly if turbidity was high, to allow photosynthesis. Deposition is interpreted to have taken place in a shallow fluvial system, perhaps one that drained a lowlying island in the Iowa Devonian sea. The very localized, lenslike geometry of the deposit is consistent with this interpretation. Furthermore, the very shallow water depositional sites interpreted for the limestones enclosing the clays and the coal suggest that, if unit 5 was indeed deposited as part of a fluvial system, the part of the system at the depositional site must have been very near base level and, therefore, very likely of low flow velocity. Low flow velocity is also suggested by the fine-grained nature of the sediments and the relatively undisturbed nature of the cuticle. The apparently monospecific composition of the flora and the fact that the cuticle in this clay tends to occur in more or less isolated strands that are not particularly contorted and intertwined supports the interpretation of local derivation of the cuticle, as long distance transport would be more likely to produce an irregular mass of cuticle composed of a mixed flora from a variety of habitats. It is clear that the floras in the vicinity of Garrison were relatively diverse during the Devonian as evidenced by the very abundant and diverse miospore flora of the shale overlying the coal, again supporting the interpretation of the local derivation of the cuticle from a flora dominated by a single species. Cuticle is generally developed to minimize desiccation of subaerially exposed plants. It seems likely that the depositional environment was subjected to occasional, perhaps seasonal, subaerial exposure.

The paper coal itself (unit 6) appears to have been deposited under conditions very similar to those of the underlying clay. The main difference between units 5 and 6 is the very low inorganic sediment content of the paper coal. The reduction in the amount of clay at the site of cuticle buildup may have been the result of a baffling effect on the perimeter of the stand of plants that contributed to the coal. It seems more likely, however, that a lessening in the influx of clays, perhaps due to a reduction or diversion of the drainage, allowed the cuticle-producing plants to flourish, and the cuticle to accumulate, ultimately to form the coal. The accumulation of the miospores associated with a probable sporangial structure in the cuticle also argues for reduced water movement. These spores are apparently immature and had not been dispersed. Had the cuticle been transported any distance, it would be expected that even the undispersed spores would have been lost in transport. Very likely, however, there was some water movement as suggested by the apparently preferred orientation of the long axes of the cuticle segments. Furthermore, the abundance of dispersed miospores in the paper coal is considerably less than that of the overlying shale. The small size and light weight of the spores allows them to be transported by a minimum of current activity. The relatively low abundance of spores in the coal suggests removal of the dispersed spores from the site by water movement.

The grayish-brown shale (unit 7) overlying the coal, as noted above, has produced an extremely abundant miospore flora. Nevertheless, no presumably marine palynomorphs, such as acritarchs and scolecodonts, have been noted in this unit. Small, carbonized plant fragments are very common in this shale, but plant cuticle is not nearly as abundant as it is in the coal or the underlying clay. Ganoid type fish scales are fairly common. The extreme abundance of miospores, as well as the carbonized plant remains suggest very quiet waters with little or no current activity. The dark color of the shale also suggests stagnation of the waters at the site of deposition. The highly calcitic content of this shale, however, is due largely to the presence of lime muds to coarse-grained carbonate sands, including fossil material such as small brachiopod fragments. The presence of these carbonate sands suggests a marine influence and greater water movement than has been interpreted above. The fish fragments, if not transported into the depositional environment, suggest that at least the surface waters were moderately well oxygenated. The reduced amount of cuticle present in this unit suggests that the environment was no longer favorable for the growth of the plants that contributed the cuticle. The apparently contradictory nature of the characteristics of this deposit suggest variability in depositional conditions. The interpretation favored in this report is that, as suggested above, deposition took place primarily in a quiet, shallow, nonmarine environment. The depositional site, however, was apparently very near sea level. The carbonate sands, and perhaps the fish material as well, may have been transported into the depositional site by storms. If this interpretation is correct, the presence of carbonate in this unit, but not in the two underlying units, suggests deposition during the early stages of a marine transgression. Introduction of marine waters and fluctuations in salinity may have made conditions unsuitable for the growth of the plants that produced the cuticle.

The grayish-brown shale of unit 7 is overlain by the light-colored, wavy-laminated to rippled, calcarenites and calcilutites of unit 8. Fish fragments like those in the underlying shale are common, but no plant remains have been noted. This limestone is thought to represent the initial advance of marine or marginal marine conditions over the depositional site. The presence of mudcracks associated with the ripple-marked sediments suggests periodic subaerial exposure.

AGE OF THE GARRISON COAL AND ADJACENT STRATA

Preliminary examination of the palynomorph samples from the coal and adjacent shales have produced a miospore assemblage including the following species: *Ancyrospora langii* (Taugourdeau-Lantz) Allen, 1965; *Cristatisporites triangulatus* (Allen) McGregor and Camfield, 1982; *Geminospora lemurata* Balme, 1962, emend. Playford, 1983; *Laiphospora membrana* (Sanders) Playford, Wicander, and Wood, 1983. The above-mentioned miospores by no means represent the complete miospore flora of these strata. The co-occurrence of *C. triangulatus* and *G. lemurata* suggests assignment of these strata to either the *Contagisporites optivus* var. *optivus* - *Cristatisporites triangulatus* or *Archaeoperisaccus ovalis* - *Verrucosisporites bulliferus* Assemblage Zones of Richardson and McGregor, 1986. Richardson and McGregor (1986, Figure 2) show that the first occurrence of *C. optivus* var. *optivus* is slightly higher than that of *C. triangulatus*. *C. optivus* var. *optivus*, *A. ovalis*, and *V. bulliferus* have not been noted at Garrison and suggest assignment to the former assemblage zone. Prior to this investigation, *Ancyrospora langii* has not been noted higher than the Iowa City Member of the Coralville Formation. This species, however, has been reported from strata as young as the Famennian (Loboziak and Streel, 1981). *Laiphospora membrana* ranges through the Cedar Valley Group and into the overlying Lime Creek Formation. The above miospore assemblage suggests a latest Givetian to earliest Frasnian age for these strata.

NOTES ON SOME OTHER PALEOZOIC CUTICLES AND CUTINITES

Devonian coals have been reported from numerous localities, and are represented by a variety of compositions. Relatively few cutinites, however, have been reported from Devonian strata. A cutinite deposit similar to that of Garrison has recently been reported from the Middle Devonian "Haikou Formation" of South China (Han Dexin, 1989). This deposit is composed of 60 - 85% or more cuticle. Cuticular material from that paper coal ranges in thickness from approximately 10 mm (tenuicutinites) to about 20 mm (crassicutinite). In the Iowa paper coal, only thin-walled cuticle, ranging from about 1.5 to 5.5 mm thick, has been recognized. No description of the isolated cuticle was provided by Han Dexin (1989), but plant fossils from the associated strata include: *Sporogonites yunnanense* (a bryophyte?), *Psilophyton* sp. (a trimerophyte), *Protolepidodendron scharianum* (a lycophyte), and *Protopteridium minutum* (a progymnosperm). The wide range in plant remains from the Haikou Formation provides little help in the determination of the contributors to either the Chinese or the Iowan paper coals. The Chinese coal was interpreted to have been formed as the resistant cuticle was transported by flowing water and concentrated under favorable conditions.

Similarly, the well known Indiana paper coal of Pennsylvanian age represents a low diversity flora (DiMichele et al., 1984). This paper coal, however, consists of only about 7.2% cutinite when fresh (Crelling & Bensley, 1980). Eggert and Phillips (1982) found no evidence of marine influence in the part of the section in which the coal occurs. The Indiana paper coal was interpreted to have been deposited in a coal swamp (Nelson et al., 1985).

The cuticular material of *Spongiophyton nanum* reported from the ?Middle Devonian of Ghana by Chaloner, Mensah, and Crane (1974) was not abundant enough to have formed a coal. Specimens were interpreted to have been transported via drainage systems and finally deposited in estuarine to fluviatile environments. They are not thought to have been part of a marine flora.

ACKNOWLEDGMENTS

The writers would like to express their appreciation to those who helped to make this study possible. In particular, we would like to thank Bill Bunker and

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PART III

STOP DISCUSSIONS AND DESCRIPTIONS

KEY

Major Lithologies

- limestone
- "sublithographic" limestone (micritic or pelletal)
- irregularly bedded limestone
- coral or stromatoporoid-rich limestone (biostrome)
- laminated limestone
- highly fractured to brecciated brecciated or intraclastic
- shale partings argillaceous
- sandstone mud clasts
- vf sandstone, siltstone, mudstone
- coal

Other Lithologic modifiers

- stylolites
- b "birdseye"
- v vuggy
- c calcite void fill
- "stromatactis" structures
- voids or fractures filled with laminated internal sediment
- △ chert

Fossils

- digitate stromatoporoids ("Idiostroma, Amphipora")
- hemispherical or laminar stromatoporoids
- T colonial tabulate corals (favositids)
- t small tabulate corals (Striatopora)
- colonial rugose corals (Hexagonaria)
- solitary rugose corals
- ⊥ overturned corals and stromatoporoids
- brachiopods
- # bryozoans
- gastropods
- crinoid debris
- trilobites
- fish teeth, plates
- plant debris
- burrows
- bivalves

STOP 1. GARRISON QUARRY, BENTON COUNTY, VULCAN MATERIALS CORP.

Stop leaders: B.J. Witzke, B.J. Bunker, J.E. Day

DISCUSSION. The Garrison Quarry exposes one of the most instructive sections of Cedar Valley rocks to be seen in Iowa (Fig. 1). However, systematic study of the Cedar Valley sequence in the Garrison area did not begin in earnest until the 1980s, with the first section of the Garrison Quarry section published by Witzke et al. (1988). The Garrison Quarry was designated the type locality for the Hinkle Member of the upper Little Cedar Formation (ibid.), named after nearby Hinkle Creek. Rogers (1990) sampled conodonts from the Little Cedar and Coralville formations at the Garrison Quarry and nearby Garrison core, and Plocher (1990) described the petrography and depositonal history of the upper Little Cedar-Coralville interval in the Garrison area. Further studies during 1991 re-evaluated the Cedar Valley interval in the Garrison Quarry, and additional contributions based on these studies are found in this guidebook (Day, brachiopods; Klug and Schabilion, coal in Lithograph City Fm.; Kralick, Lithograph City conodonts; Parse and Plumley, paleomagnetic studies).

We will begin our examination of the Garrison Quarry section along the main ramp paralleling the north face of the quarry (Fig. 1). The Garrison Quarry section is placed in stratigraphic context by comparison with the nearby Garrison core, located about 0.5 miles (O.8 km) to the southwest of the quarry (Fig. 2). ***Hard hats are required at all times in the quarry; please stay clear of quarry high walls and any unstable faces.*** The upper half of the Eagle Center Member, Little Cedar Formation, is exposed at the bottom of the quarry and along the lower ramp, and is primarily characterized by faintly-laminated cherty dolomite (see section description, units 1-5). Hummocky to low-angle cross-laminations are identified, with some thin skeletal packstone units showing megaripple bedforms; these sedimentary features indicate that deposition occurred above storm wavebase. Plocher (1990) recognized that the Eagle Center Member, although dolomitized to varying degrees, includes wackestone-packstone and grainstone facies in the Garrison area. Fossils include scattered brachiopods (*Neatrypa*, *Orthospirifer*), crinoid debris, stromatoporoids, placoderm plates, and burrows. Conodonts are not abundant in the Eagle Center Member at Garrison, but Rogers (1990) identified *Icriodus subterminus*, *I. brevis*, *I. l. latericrescens*, "*Polygnathus varcus* group," and *P.* spp., characteristic of the lower *subterminus* Fauna.

The overlying Hinkle Member (type section) includes a variety of contrasting lithologies, primarily dense, very finely crystalline to sublithographic limestones (units 6-8, Fig. 1). Irregular laminations, stromatolitic and "birdseye" structures, internal sediment fills, and brecciation are consistent with deposition in peritidal and supratidal settings. The Hinkle forms the final regressive phase of deposition of the Little Cedar cycle.

The succeeding depositional cycle includes strata of the Coralville Formation, which are easily accessed along the quarry ramp (units 9-16, Fig. 1). The Coralville interval forms a general shallowing-upward depositional sequence, with the Gizzard Creek Member marking the maximum transgressive phase of the cycle. Dolomitized fossil-moldic wackestone fabrics characterize the Gizzard Creek, with scattered to common atrypid brachiopods (*Independatrypa*). Conodonts from the member at Garrison include *Icriodus subterminus*, *Polygnathus angustidiscus*, and *Mehlina gradata* (Rogers, 1990; our collections), characteristic of the upper *subterminus* Fauna. Overlying units of the Cou Falls Member are prominently biostromal, containing abundant branching and globular stromatoporoids. Upper Coralville strata of the Iowa City Member are dominated by sublithographic limestones, laminated and intraclastic in part. Common "birdseye" structures indicate deposition in supratidal settings, in part. A minor flooding event is noted in units 15-16, which contains exceptionally large ostracodes and scattered *Athyris* and includes stromatoporoids and gastropods to the south. The ramp section is capped by units assigned to the Lithograph City Formation.

Previous studies mistakenly assigned units 20-26 to the Coralville Formation (Witzke et al., 1988). Further investigations along the upper bench in the south quarry area demonstrated the

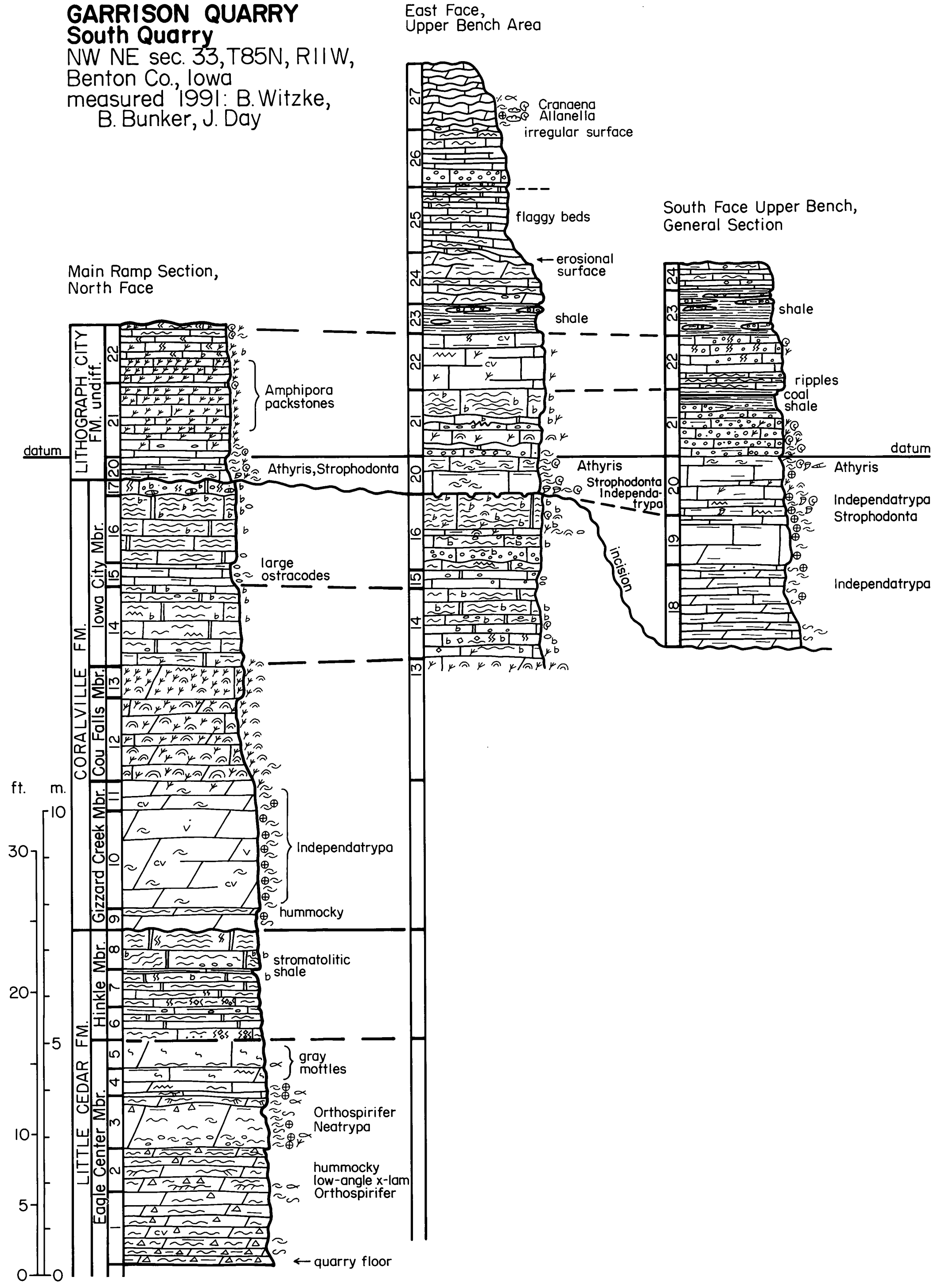

Figure 1. General stratigraphic section exposed at the Garrison Quarry. Number units are described in text.

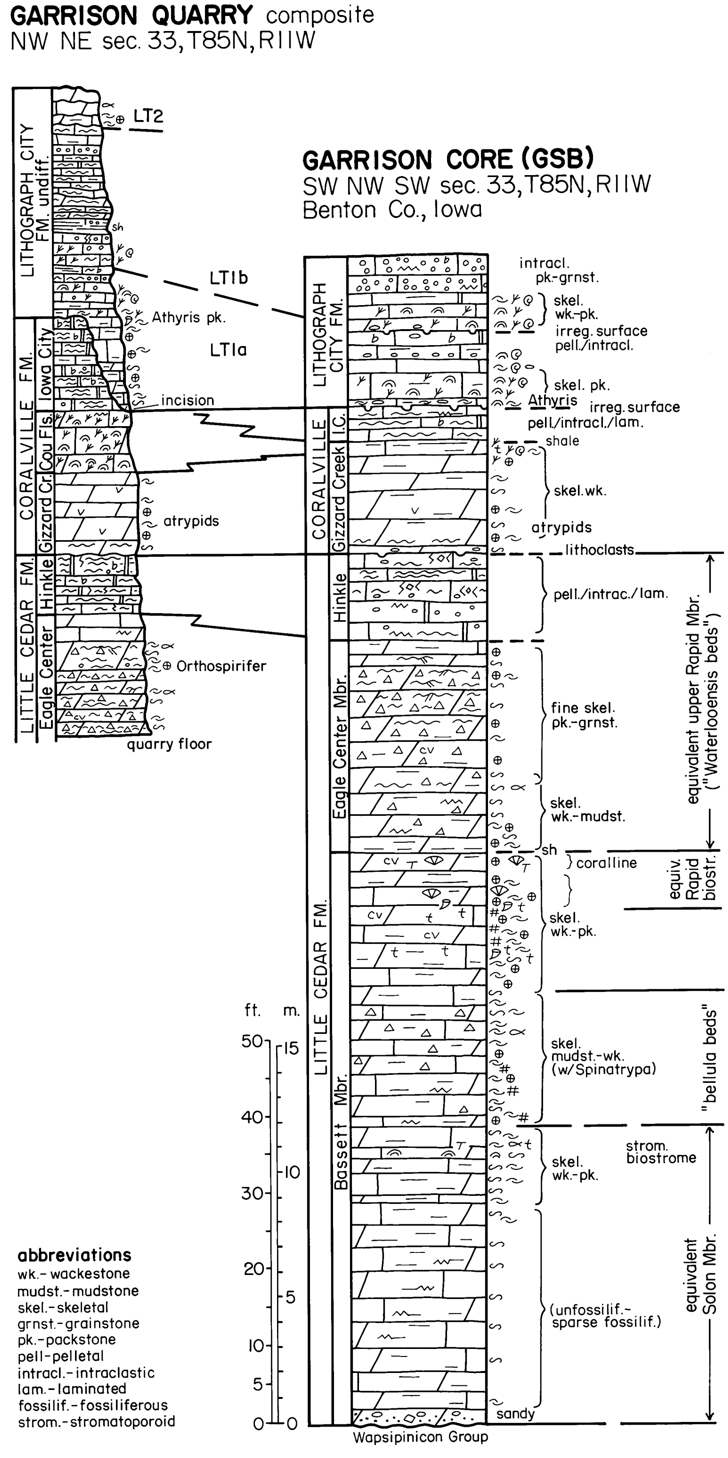

Figure 2. Comparison of Garrison Quarry section to nearby Garrison core.

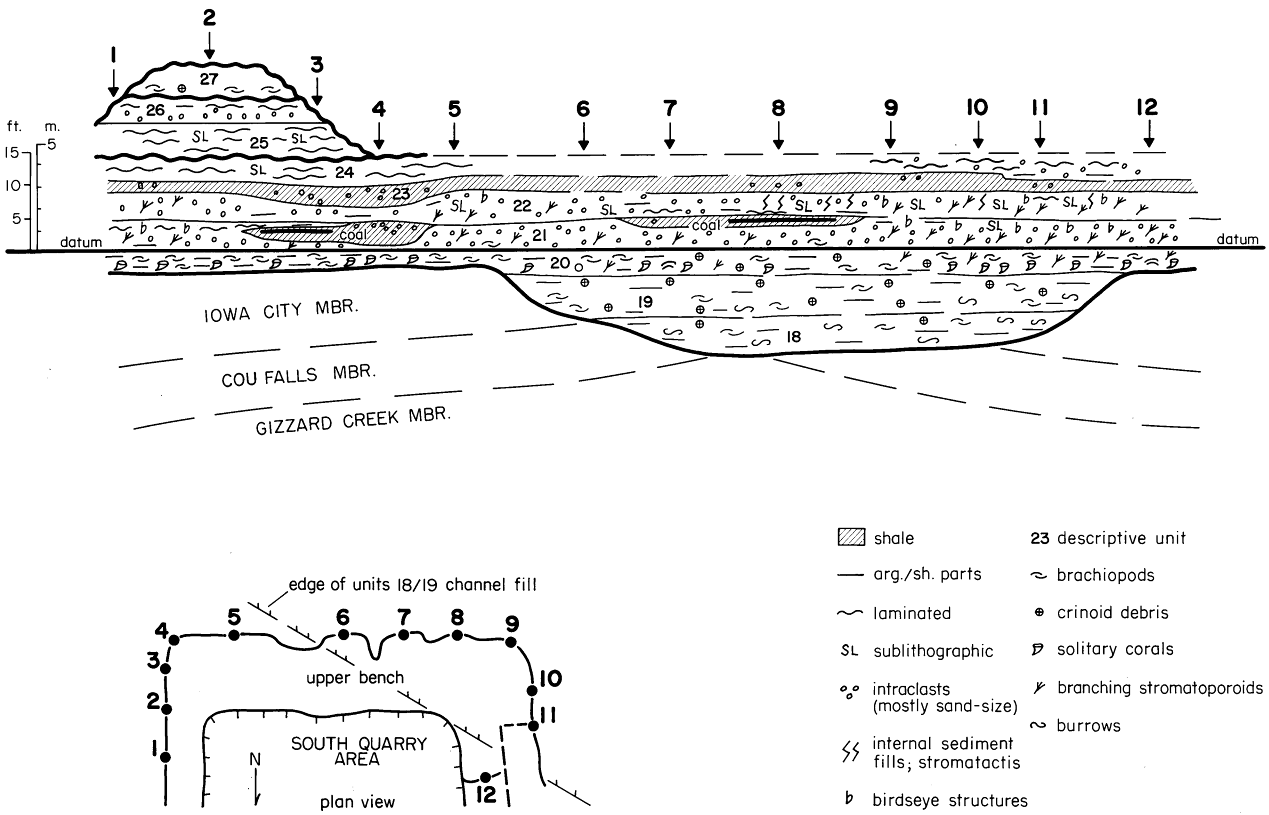

Figure 3. Stratigraphic relations within the Lithograph City Formation, Garrison Quarry, upper bench in south quarry area. Datum is top of unit 20, and extant folds are not portrayed; station 2 is in the center of a syncline. Figure is vertically exaggerated.

presence of a prominent unconformity surface above units 16-17 of the Coralville Formaton, and previously unrecognized units (18-19) were found to occupy a channel-like cut-out above Coralville strata in the southwest corner of the quarry (Fig. 3). Brachiopods (Day, this guidebook) and *insita* Fauna conodonts (Kralick, this guidebook) in units 18-20 are characteristic of lower Lithograph City strata elsewhere in eastern Iowa, and the interval above this unconformity surface at Garrison is thereby assigned to the Lithograph City Formation. The channel-like cut-out in the quarry trends roughly to the southeast (Fig. 3), and apparently extends in a broad swath at least as far as the Garrison core (Fig. 2) 0.5 miles (0.8 km) to the southwest. This suggests that a southeast-trending erosional channel 0.5 miles (0.8 km) or more across was formed above the Coralville Formation prior to marine inundation during the succeeding Lithograph City depositional cycle. Basal Lithograph City strata are observed to rest on various Coralville units (units 11-17, Figs. 1, 3), indicating sub-Lithograph City erosional relief of about 23 feet (7 m) or more in the Garrison area.

The stratal geometries of lower Lithograph City units at Garrison are grossly similar to those noted in the lower Lithograph City Formation in Johnson County to the southeast, where the State Quarry Member occupies broad channels (up to 0.9 mi [1.5 km] wide, 60 ft [18 m] relief) incised into underlying Coralville and Little Cedar units. It is tempting to suggest that units 18-19 at Garrison represent proximal channel-filling estuarine-like facies correlative to part of the State Quarry Limestone. It is possible, therefore, that broad southeast-trending sub-Lithograph City erosional channels extended 40 miles (65 km) or more from Benton County to the inner shelf margin of the

Coralville Formation in Johnson County (see block diagrams in Bunker et al., 1986). These channels were the initial sites of basal Lithograph City deposition, but marine deposition overstepped the channel margins regionally as the seaway expanded. Basal Lithograph City strata to the north (Osage Springs Mbr) may correlate to the initial marine expansion out of the State Quarry-Garrison channels (unit 20, Garrison) or, alternatively, may mark regional expansion of the seaway during a subsequent marine cycle (possibly the cycle represented by unit 27 at Garrison). Further study is needed.

Field trip participants will proceed to the upper bench in the south quarry area for the final leg of Stop 1. A series of exposures in this area (Fig. 3) display complex facies relations within the Lithograph City Formation. Structural complications and discontinuous exposures in the south quarry area hinder examination. A prominent syncline is developed at station 2 (Fig. 3), and minor sub-Lithograph City flexure is centered near station 8. Because of small-scale folding in this area, the cross section (Fig. 3) is hung on a stratigraphic datum (top of unit 20). The exposed sequence of Lithograph City strata contains three minor transgressive-regressive marine cycles (labeled LT1a, LT1b, LT2 on Fig. 2), which encompass units 18-21, units 22-26, and unit 27, respectively. The first cycle contains burrowed skeletal mudstones and wackestones with normal-marine fauna in the lower part (see section description). This lower interval oversteps the eroded Coralville surface, with a locally developed encrusted hardground surface at the base of unit 20 in the southeast stations. The interval is capped by a regressive package (unit 21) locally containing intraclastic packstones and *Amphipora* packstones. The upper part locally displays "birdseye" structures and laminated sublithographic limestones suggestive of supratidal and peritidal deposition (Fig. 1). A discontinuous green-gray shale occurs at this position, and an unusual cuticle-rich coal occurs near the top of the shale, best seen at station 3 (see Klug and Schabilion, this guidebook).

A minor restricted-marine flooding event is recorded in unit 22, which contains *Amphipora* wackestones and packstones. This unit grades upward into intraclastic and "birdseye"-bearing laminated strata; internal sediment fills and calichified fabrics record subaerial exposure at the top of unit 22. A prominent green-gray to gray shale (unit 23) occurs above, locally containing intraclastic and nodular limestone lenses. This is capped by flaggy carbonate mudstones which are erosionally truncated at the top. Although lacking normal-marine facies, units 23-24 record a raising and lowering of base levels and are considered to form a minor cycle of deposition. A similar package of carbonates above (units 25-26) is also erosionally truncated at the top, forming another minor depositional cycle. A third marine flooding event is recorded in unit 27 (seen only at station 2, Fig. 3), which contains characteristic brachiopods, conodonts (*P. insita*), and other fossils. In conclusion, the Lithograph City Formation in the Garrison area is comprised of a series of small-scale transgressive-regressive depositional cycles. In this respect, the sequence closely resembles that seen across northern Iowa. However, precise correlation of these small-scale cycles within the Lithograph City Formation has yet to be accomplished in the Iowa area.

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GARRISON QUARRY

LOCATION: South Quarry
NW NE Section 33, T85N, R11W, Benton Co., Iowa
Measured April-July, 1991: B. Witzke, B. Bunker, J. Day

CEDAR VALLEY GROUP
Lithograph City Formation (undifferentiated)

UNIT 27
Dolomitic limestone to calcitic dolomite, v.lt.yel.brn. to buff, rubbly to irregular bedded, slightly overhanging at base, recessive in upper half; mudstone to skeletal wackestone, scattered lithoclasts at base; fossils in lower 75 cm include brachiopods (*Cranaena, Allanella, Athyris*), bivalves (pterioids, paracyclids), gastropods, scattered crinoid debris; upper 75 cm with indet. skeletal debris, fish bone scrap; unit is exposed only in sag of small syncline 70 m north of southeast corner of quarry; 1.5 m thick.

UNIT 26
Limestone, interbedded thin flaggy beds and finely intraclastic beds (sand-sized clasts), intraclastic strata best developed in lower half; base of unit locally sublithographic, finely laminated to flaggy in upper half, irregular to undulatory laminations (stromatolites?) and thin shale partings locally near top; upper surface irregular, erosionally bevelled, locally stained red; unit exposed only in southeast quarry area; 1.15-1.5 m thick.

UNIT 25
Limestone, dense to flaggy, vf. xlln. to sublithographic; lithographic limestone bed with glassy fracture locally at top; laterally discontinuous dolomite bed to 15 cm thick in lower part, red-brown, finely intraclastic (sand-sized clasts); mudcracks locally in basal interval; much of unit is finely and faintly laminated; basal unit onlaps lower truncation surface; exposed only in southeast quarry area; 1.1-1.65 m thick.

UNIT 24
Limestone, dolomitic limestone, and dolomite; limestones are flaggy, lt.gr.-lt.brn.gr., mudstone, sublithographic in part, part finely laminated, scattered small intraclasts along some laminae; dolomite and dolomitic limestone intervals occur in basal 20-22 cm and upper 0-58 cm (laterally truncated), red-brown to gray, part with small intraclasts, discontinuous shaly partings, irregular laminations, both dolomite beds display irregular upper bedding surfaces; upper surface laterally displays up to 60 cm of erosional truncation below Unit 25; unit exposed only in south quarry area; Note: units 23 and 24 may share partial facies relations; 60-135 cm thick.

UNIT 23
Shale with interbedded to nodular limestone; shale, lt.-m.gr. and grn.gr., oxidized to yel.brn., soft to chunky, calc.; thin lenses and concretionary nodules of limestone, arg., shaly partings, scattered to abundant small intraclasts (dominantly sand-sized clasts, some pebbles), intraclastic packstones in part, lenses to 25 cm thick, flaggy, concretions to 40 cm diameter; primarily unfossiliferous, scattered *Amphipora* grains locally near base; unit exposed only in south quarry

area; Note: Units 23 and 24 may share partial facies relations; 60-110 cm thick.

UNIT 22

Limestone, ledge former, displays significant lateral variations within quarry; *lower beds* characterized by *Amphipora* wackestones and packstones through most of quarry, biostromal in part, laterally replaced by interlaminated mudstones and intraclastic packstones along part of south quarry wall, laminated and flaggy, argillaceous in part; *middle beds* include scattered to common *Amphipora* in much of quarry, biostromal in part, laterally interbedded with flaggy, laminated, intraclastic, and sublithographic beds, scattered birdseye and internal sediment fills; *upper beds* include *Amphipora* packstones in western quarry area, laterally interbedded with laminated and intraclastic strata, sublithographic in part, with scattered to common birdseye laminations, stromatactis, and internal sediment fills, soil-like calichified and calcitic strata in south quarry wall; *Amphipora*-bearing strata include scattered *Idiostroma*, domal stromatoporoids, ostracodes, *Athyris*, and gastropods; 1.0-1.8 m thick (may locally thin to 50 cm beneath thick Unit 23 shale in southeast corner of quarry).

UNIT 21

Limestone and shale interval, displays significant lateral variations within quarry; *lower beds* dominated by packstone of small intraclasts through most of quarry, locally an intraclastic grainstone, clasts dominantly sand-sized, locally includes pebble-sized clasts, oncolites noted in southwest corner of quarry, residues with quartz silt/sand, part slightly argillaceous, scattered to common *Athyris* and *Amphipora* (abraded grains in part), locally includes *Amphipora* packstones (especially to north), scattered massive stromatoporoids and gastropods, upper surface of lower beds display erosional relief (to 5 cm) in southeast quarry area; *middle beds* include small intraclastic packstones to wackestones, laterally replaced by *Amphipora* wackestones to packstones, biostromal in part (primarily in west and north quarry areas), locally with gastropods and domal stromatoporoids, intraclastic strata interfinger with laterally-discontinuous green-gray shale in southeast quarry area; *upper beds* display greatest variation, *Amphipora* wackestones to packstones common in west and north quarry areas, locally with massive stromatoporoids, *Athyris*, gastropods, laterally interfingers with skeletal to nonskeletal mudstones, stylolitic, sublithographic in part, locally laminated, scattered to common birdseye structures (primarily in south quarry area); upper beds include discontinuous shale (15-125 cm thick) in portions of southeast and south-central quarry walls, green-gray to gray, soft to chunky, calcareous, interfingers laterally with thin intraclastic limestone beds, locally with nodules of argillaceous limestone (to 50 cm diameter), carbonaceous partings near top, 5 to 12 cm below top of shale interval is a laterally-discontinuous coal 1-4 cm thick, very low specific gravity, abundant plant cuticle, coal has only limited distribution in quarry near southeast corner and along south-central wall; Note: entire Unit 21 interval is represented by shale in small area near southeast corner, shale may cut across lower beds; top of Unit 21 locally irregular; 90-155 cm thick.

UNIT 20

Limestone, light gray, skeletal wackestone to packstone, slightly argillaceous and recessive, argillaceous streaks or shaly partings, thin shales (to 4 cm) locally at top or bottom; scattered to abundant *Athyris*, packed in part; stromatoporoids scattered to common, primarily in upper part (includes *Amphipora*, *Idiostroma*, and massive forms 2-7 cm diameter); Unit 20 irregularly and unconformably overlies strata of the Iowa City Member (Units 16-17) through most of the quarry, base of Unit 20 locally an encrusted hardground surface capped by medium to dark gray fossiliferous shale, scattered lithoclasts (of Iowa City Member), scattered to common solitary rugose corals, *Independatrypa*, *Athyris*, planispiral gastropods, encrusting auloporids and spirorbids; Unit 20 conformably overlies Unit 19 in south-central and southwest quarry area, scattered to common solitary rugosans, crinoid stems/columnals, gastropods, *Independatrypa*, *Athyris*, *Allanella*, *Strophodonta*, rare nautiloids; irregular upper surface (to 7 cm relief) locally in southeast quarry area; 53-120 cm thick (thinnest along north ramp, thickest above Unit 19 in southwest quarry area).

UNIT 19

Limestone, dolomitic in part, lt.gr.-brn.gr., slightly argillaceous, with scattered argillaceous to shaly partings, medium to thick bedded, fine skeletal wackestone to packstone, minor thin grainstones, thin (1 cm) sublithographic limestone locally at base; scattered to common brachiopods (*Independatrypa*, *Strophodonta*) and fine to coarse crinoid debris, solitary rugose corals (upper part), scattered *Amphipora* (locally in top 10 cm); scattered burrow mottles; unit conformably overlies Unit 18, oversteps edge to unconformably lie on Coralville strata marginally (Units 13-16); Unit 19 exposed only in southwest quarry area; 0-1.7 m thick.

UNIT 18

Dolomitic limestone to calcitic dolomite, more dolomitic downward, lt.brn.gr.-chocolate brown, argillaceous mudstone to skeletal wackestone, scattered shaly partings and arg. streaks; scattered to common horizontal burrow fabrics and prods, irregular gray mottles common in upper beds; scattered organic specks and dark sand-sized grains (phosphatic?) locally in upper part; sparse skeletal content, more abundant in some stringers, crinoid debris, brachiopods (*Independatrypa*, *Allanella*, *Schizophoria*, & *Strophodonta*); unit is poorly exposed in part, unconformably overlies Coralville Formation (Units 11-13); Unit 18 exposed only in southwest quarry area; approximately 0-2.0 m thick.

Coralville Formation
Iowa City Member

UNIT 17

Limestone, v.lt.gr., porous, sublithographic in part, irregular surface below (to 8 cm relief), large clasts of sublithographic limestone (to 10 cm) at base, small intraclasts or lithoclasts scattered through, upper part with internal sediment fills, scattered pyrite, and birdseye structures (top 7 cm); irregular upper surface; unit is recognized only in north ramp area, probably a local fill on Unit 16 exposure surface; 0-33 cm thick.

UNIT 16

Limestone, pale brn., sublithographic to xf. xlln., dense, medium to thick bedded, faint to prominent laminae common through much of unit, scattered stylolites; calcite spar spots and birdseye structures observed through most of quarry, generally increasing in abundance upward; lower to middle beds locally include fine intraclastic packstones; scattered ostracodes (thin packstone lenses or isolated large valves); birdseye-bearing beds laterally interfinger with skeletal wackestones to packstones in south quarry area, stromatoporoids (*Amphipora*, small domal forms), *Athyris*, gastropods; irregular upper surface, laterally truncated beneath Units 18-20; 0-1.9 m thick.

UNIT 15

Limestone, pale gray, skeletal mudstone, wackestone, and packstone, scattered small intraclasts; rubbly bedded, recessive unit; scattered to common large ostracodes (2-10 mm), rare *Athyris*; laterally truncated beneath Units 18-19; 0-50 cm thick.

UNIT 14

Limestone, pale brown, dense, sublithographic to xf. xlln., scattered stylolites; faintly laminated through much of unit, irregular to disrupted laminae locally near top, prominent birdseye laminations common in upper part, birdseye scattered to common through much of unit; scattered small intraclasts locally interfinger with laminated strata; thin shale partings along some bedding surfaces; lower beds locally fractured to slightly brecciated; scattered ostracodes and gastropods; scattered stromatoporoids at base (*Amphipora*, *Idiostroma*, rare domal forms); sharp bedding break at top; unit is laterally truncated beneath Units 18-19; 0-1.8 m thick.

Cou Falls Member

UNIT 13

Limestone, dolomitic, pale brown, forms resistant overhanging bed, stylolites near top; common to abundant *Idiostroma*, packed to biostromal in part, scattered to common spherical to irregular massive stromatoporoids (2-10 cm diameter); sharp lithic change at top but apparently conformable with Unit 14; laterally truncated beneath Units 18-19; 0-70 cm thick.

UNIT 12

Dolomite, calcitic, v.lt.brn., skeletal wackestone to packstone, dolomitic matrix, fossils are entirely calcitic; recessive interval, rubbly bedded, scattered argillaceous partings; common to abundant stromatoporoids, packed to biostromal in part, subequal mixtures of branching *Idiostroma* and irregular to spherical massive stromatoporoids (2-30 cm diameter), rare *Athyris* in lower part; conformably overlain by Unit 13, laterally truncated beneath Unit 18; 0-1.8 m thick.

Gizzard Creek Member

UNIT 11

Dolomite, v.lt.brn., slightly calcitic at top, calcite void fills in lower part; in 2 to 3 beds; thin stringers with common molds of *Independatrypa* at 8, 37, and 50 cm above base of unit; scattered molds of small crinoid debris, less common upward; top 10 cm with scattered to common *Idiostroma* (calcitic fossils); prominent bedding break at top; conformable contact with Unit 12; unconformably overlain by Unit 18 locally along south-central quarry face; 60-65 cm thick.

UNIT 10

Dolomite, v.lt.brn.gr., xf.-vf. xlln., generally massive with discontinuous bedding breaks (especially 1.1 m above base); porous and vuggy, scattered calcite void fills; skeletal-moldic wackestone fabrics, scattered to common crinoid debris molds, brachiopod molds common through most (primarily *Independatrypa*, scattered *Athyris*), gastropods noted; slightly less skeletal in upper 65 cm; 2.13 m thick.

UNIT 9

Dolomite, v.lt.brn., vf. xlln., scattered m.gr. burrow mottles, scattered small crinoid debris molds in upper part; top 6 cm displays low-angle to hummocky cross-laminations; 43 cm thick.

Little Cedar Formation
Hinkle Member (Type Section)

UNIT 8

Limestone, pale brown, sublithographic, finely to irregularly laminated through most; lower half with scattered small intraclasts and birdseye structures, laminations outline domal stromatolitic-like structures, irregular surface near middle of unit capped by birdseye-bearing limestone; upper half is highly fractured, irregular upper surface, thin shale parting at top; 85 cm thick.

UNIT 7

Limestone, pale brown, dense, in 3 or more beds, xf.-f. xlln. and sublithographic; faintly and finely laminated through most, irregular laminations near base, crinkly to wavy laminations and birdseye structures in upper limestone bed; internal sediment fills and fracture-breccia clasts scattered in unit; top 11 cm is shale, lt.gr., calcareous, with thin stringers of dense arg. limestone; 84 cm thick.

UNIT 6

Limestone, pale to lt. brown, xf.-f. xlln. and sublithographic, dense; rubbly bedded at base, medium bedded upward; faintly laminated in part, slightly brecciated near base; scattered small intraclasts and argillaceous partings near top; discontinuous stringers with fine quartz sand near base; sharp contact below; 73 cm thick.

Eagle Center Member

UNIT 5

Dolomite, calcitic, lt.brn., xf. xlln., dense, glassy fracture, one bed; faint laminae at base, irregular medium gray mottling through rest of unit, phosphatic fish debris noted near base; sharp lithic break at top; 60 cm thick.

UNIT 4

Calcitic dolomite and dolomitic limestone, in 2 to 3 beds; basal interval is a skeletal packstone to grainstone of variable thickness (1-20 cm), faint low-angle cross-laminations, probably a megaripple bedform, stylolitic, phosphatic fish debris common at base, crinoid debris, brachiopods scattered to common (especially *Orthospirifer*, but including *Schizophoria, Shuchertella*); upper bed displays irregular medium gray mottling, stylolites; thin shale at top of unit; 64 cm thick.

UNIT 3

Dolomite, part calcitic, lt.brn., massive, weakly laminated in part; stringers of fine to coarse skeletal packstone (dolomitic limestone in part) scattered through, intraclasts noted in lower 25 cm, top packstone unit displays starved megaripple bedform; packstones are crinoidal in part, scattered to common brachiopods, *Orthospirifer* through most (particularly common in upper half), *Neatrypa waterlooensis*, scattered fish bone/teeth, rare small branching or encrusting stromatoporoid grains noted 25 cm above base; argillaceous partings and chert nodules locally in upper part; packstone stringers and laminae are disrupted laterally by burrow mottling; 1.1 m thick.

UNIT 2

Dolomite, lt.brn., in 3 beds, faintly laminated, displays horizontal laminations and low-angle to hummocky cross-laminations; cherty, nodules of smooth to chalky chert, part finely laminated, abundance varies laterally, nodules locally 10 to 20 cm thick, 50 to 100 cm lateral dimension, thin chalky siliceous mottlings scattered within dolomite; scattered phosphatic fish debris and *Orthospirifer*; shale parting, m.gr., at top (to 5 cm); 98 cm thick.

UNIT 1

Dolomite, lt.brn.gr., vf. xlln., slightly argillaceous, faintly laminated, slightly calcitic in upper bed, bedded 10-20 cm, argillaceous partings along bedding breaks, scattered calcite void fills; scattered burrow fabrics, scattered *Orthospirifer* (especially in upper bed); very cherty in lower part, less cherty above, cherts are lt.gr. to white, smooth to chalky, small siliceous blebs to nodules, nodules to 1 m diameter in lower beds; unit forms floor in much of quarry, measured along east wall; 1.6 m thick.

STOP 2. PALO QUARRY, LINN COUNTY, IOWA

Discussion by Jed Day

DISCUSSION. The Devonian section at Palo Quarry (Fig. 1) is unique in various respects because it is one of the few surface localities where subtidal open-marine strata of the Rapid Member are directly overlain by peritidal deposits of the Hinkle Member of the Little Cedar Formation, near the distal edge of the progradational peritidal facies of the Hinkle (Witzke et al., 1989, p. 232, fig. 8D). A thin (0.45 m) succession of the Cou Falls Member of the Coralville Formation is developed immediately above the Hinkle at this locality (Fig. 1). The boundary between the Little Cedar and Coralville depositional sequences is paraconformable at this locality, although regionally it is disconformable. The facies transition between the skeletal limestones of the Rapid and cherty skeletal dolostones of the Eagle Center members takes place between the Palo (STOP 2) and Garrison (STOP 1) quarries. Detailed petrographic and isotopic studies of the Devonian section at Palo Quarry were done by Plocher (1990).

Substantial differences between Rapid and Eagle Center Member faunal assemblages are noted between the two quarry sections as well. At Palo Quarry, Rapid Member assemblages are characterized by moderate to high faunal diversity (echinoderm and brachiopod-dominated), whereas Eagle Center strata at Garrison Quarry (STOP 1) are characterized by low diversity (brachiopod-dominated) assemblages (see Day, this guidebook). Rapid Member brachiopod faunas in the lower part of the Palo Quarry section occur with conodonts of the Lower *subterminus* Fauna (Rogers, 1990, table 12), and correlate with the upper part of the *Neatrypa waterlooensis* Zone (Day, this guidebook). Common to abundant articulated rhombiferans (*Strobilocystites calvini*; Thomas, 1924; Stainbrook, 1941) occur in units 3-9 (Fig. 1) of the Rapid Member on the north side of the Palo Quarry. The same cystoids occur in the upper part of the Rapid and the lower Cou Falls Member of the Coralville Formation at the Mid-River Marina Quarry (Thomas, 1924; see Plocher, STOP 3A) in Johnson County.

Brachiopods from the Cou Falls Member (Fig. 1, unit 15) of the Coralville Formation at Palo Quarry constitute the Lower *Athyris* Fauna of Day (1989) and the *Athyris* Fauna of Day (this guidebook). The Cou Falls *Athyris* Fauna at Palo Quarry, correlates with other basal Cou Falls faunas in Johnson (*Cranaena* Fauna) and Scott (lower *Strophodonta* Fauna) counties, and Gizzard Creek Member faunas at Garrison Quarry (STOP 1; *Independatrypa* Fauna of Day, this guidebook), and the Glory Quarry (*Tecnocyrtina* Fauna of Day, 1989, and Day, fig. 9, this guidebook) of the *Tecnocyrtina missouriensis* Zone (Day, this guidebook) The aforementioned Cou Falls and Gizzard Creek brachiopod faunas occur with conodonts of the Upper *subterminus* Fauna (Witzke et al, 1989; Day, 1989; Rogers, 1990), which are correlated with a position in the upper part of the *disparilis* Zone.

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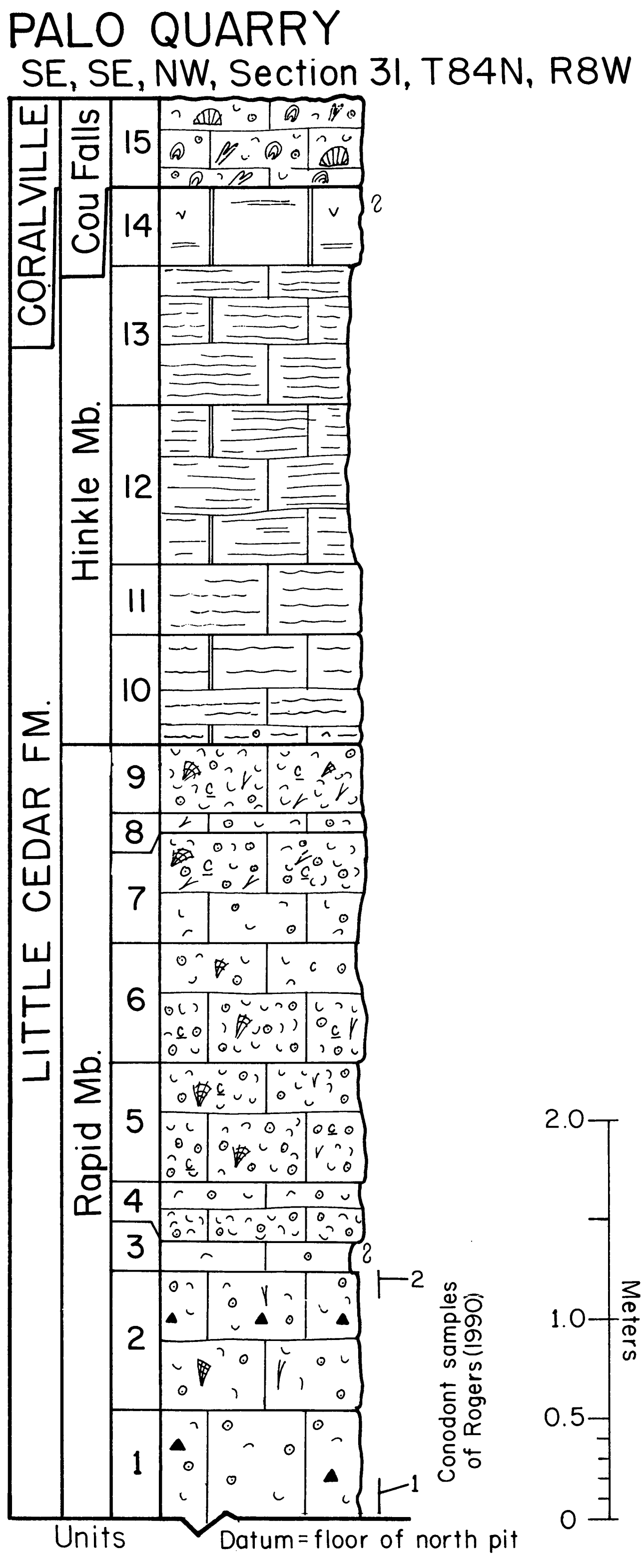

Figure 1. Devonian section (late Givetian) at the Palo Quarry in eastern Linn County, Iowa, featuring the upper part of the Rapid and Hinkle members of the Little Cedar Formation, and the lower part of the Cou Falls Member of the Coralville Formation. Adapted from section description of Plocher (1990).

PALO QUARRY

LOCATION: SE 1/4, SE 1/4. NW 1/4, Section 31, T84N, R8W
Section description and location modified from: Plocher (1990); measured section by Bill Bunker, Fred Rogers, Brian Witzke, and Jed Day, 5/19/87; and Witzke et al., 1989, fig. 8D

CEDAR VALLEY GROUP
Coralville Formation
Cou Falls Member (0.45 m)

UNIT 15
Ls., coralline & stromatoporoid rich fine grained calcarenite; very fossiliferous, abundant stromatoporoids, *Favosites* sp., *Hexagonaria* sp., brachiopod and echinoderm debris. Contains the brachiopods *Athyris vittata*, *Neatrypa waterlooensis*, *Tylothyris subvaricosa*, and *Cranaena iowensis* (see *Athyris* Fauna, fig. 9, of Day this guidebook; Day, 1989a); 45 cm.

Little Cedar Formation
Hinkle Member (2.80 m)

UNIT 14
Ls., sublithographic calcilutite; sharp upper contact, irregular bedded, thin shaley partings, small calcite filled voids, large sub-vertical burrows, scattered faint laminations, unfossiliferous; 40 cm.

UNIT 13
Ls., unfossiliferous burrowed calcilutite; irregular bedding, slightly recessive unit, thin shaley partings, faintly finely laminated; 70 cm.

UNIT 12
Ls., unfossiliferous calcilutite; irregular bedding, unit is recessive, laminated; 80 cm.

UNIT 11
Ls., unfossiliferous calcilutite; irregular bedding, shaley parting at top of unit, discontinuous laminations; 35 cm

UNIT 10
Ls., unfossiliferous calcilutite; very thinly bedded, laminated, rare echinoderm and brachiopod debris; 55 cm.

Rapid Member (3.89 m)

UNIT 9
Ls., coarse grained echinoderm calcarenite; abundant brachiopod and bryozoan debris, cystoids (*Strobilocystites* sp.) common, occurs as a single thick bed, contains scattered brachiopods including *Neatrypa waterlooensis*, *Schizophoria laudoni*, and *Cyrtina* sp.; 35 cm.

UNIT 8
Ls., mixed skeletal calcilutite; abundant crinoid, brachiopod, and bryozoan grains, brachiopod fauna similar to Unit 7; 10 cm.

UNIT 7

Ls., mixed skeletal calcilutite, grading up to a mixed skeletal calcarenite; thinly bedded, abundant brachiopod, echinoderm (cystoid), and bryozoan debris, containing the brachiopods *Schuchertella* sp., *Pentamerella* sp., *Neatrypa* sp., *Orthospirifer* cf. *iowensis*, *Tylothyris subvaricosa*, large *Schizophoria laudoni*, and *Elita* sp.; 55 cm.

UNIT 6

Ls., mixed skeletal calcarenite, grading to a skeletal calcilutite; abundant bryozoan, crinoid, and brachiopod debris, with common cystoids, containing brachiopods similar to fauna in Unit 7; 60 cm.

UNIT 5

Ls., mixed skeletal calcarenite; abundant brachiopod, echinoderms, with scattered bryozoans, and common cystoids, containing the brachiopods *Orthospirifer* sp., *Tylothyris* sp., *Eosyringothyris* sp., *Neatrypa* sp., *Schizophoria laudoni*, and *Schuchertella* sp.; 60 cm.

UNIT 4

Ls., mixed skeletal calcarenite, grading up to skeletal calcilutite; abundant echinoderm and brachiopod debris, containing *Eosyringothyris* sp., *Neatrypa* sp., *Orthospirifer iowensis*, *Tylothyris* sp., and *Cupularostrum cedarensis*; 30 cm.

UNIT 3

Ls., sparsely fossiliferous calcilutite; recessive, burrowed, with scattered brachiopod and echinoderm debris; 15 cm.

UNIT 2

Ls., mixed skeletal calcilutite; with chert nodules 25 cm from top of unit, abundant brachiopod and echinoderm debris, contains the brachiopods *Neatrypa waterlooensis*, *Schizophoria laudoni*, and *Cyrtina* sp., the bryozoan *Sulcoretopora* sp.; contains the conodonts (Rogers, 1990, sample 2, table 12) *Icriodus subterminus* and *I. brevis* in the upper 15 cm (=Lower *subterminus* Fauna); 70 cm.

UNIT 1

Ls., mixed skeletal calcilutite; abundant brachiopod and echinoderm grains, with scattered chert nodules (up to 12 cm), with *Neatrypa waterlooensis* in lower 20 cm, with *Orthospirifer* cf. *iowensis* in upper 34 cm.; contains *Icriodus subterminus*, *I. brevis*, and *Polygnathus* sp. in basal 20 cm (Rogers, 1990, sample 1, table 12); 54 cm.

STOP 3. MID-RIVER MARINA QUARRY

Discussion by Orrin W. Plocher

DISCUSSION. The Mid-River Marina Quarry is one of four remaining abandoned quarries in the area where present day Highway 965 and Interstate 380 cross the Iowa River in northern Johnson County. Two additional quarries reportedly were filled during the construction of the Interstate. The closest quarry to the Mid-River Marina, the Mid-River Marina Quarry, is the largest remaining quarry. Portions of the Little Cedar and Coralville formations are exposed in the quarry, providing an excellent look at the contact between the two formations (T-R cycles).

The Rapid Member of the Little Cedar Formation is exposed in the lower portion of the quarry. At this location, the upper regressive portion of the Rapid Member consists of echinoderm packstone and grainstone units that are interpreted as sediment pulses off a nearby shoal axis. Units in the upper Rapid Member are quite variable over a small area (Fig. 1), creating a shoal-offshoal facies mosaic. Trace elemental and stable isotopic data of skeletal grains and calcite cements suggest that portions of the shoal were periodically emergent during the regression at the end of deposition of the Little Cedar Formation (Plocher & Ludvigson, 1989; Plocher, 1990; Plocher et al., 1990a, b) resulting in

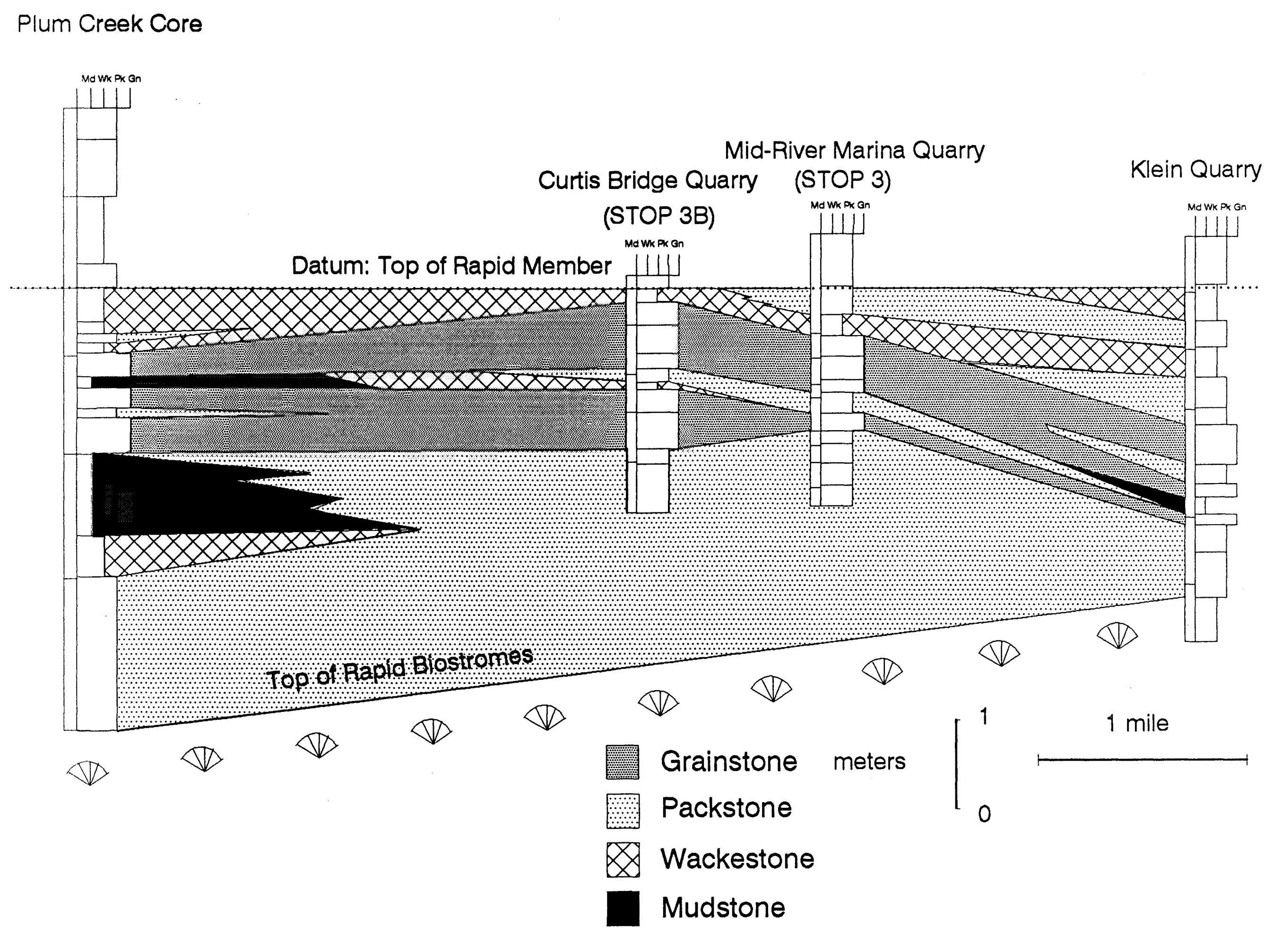

Figure 1. Graphic cross-section through the "Curtis Bridge" grainstone.

the development of small meteoric phreatic lenses and meteoric phreatic alteration. During this regression, small local meteoric systems were developed only on the main shoal axis. The regional exposure surface for this regression is to the northwest between Palo Quarry (STOP 2) and Garrison Quarry (STOP 1).

The overlying Coralville Formation consists of the Cou Falls Member and the overlying Iowa City Member. The Mid-River Marina Quarry is the type section for the Cou Falls Member (Witzke et al., 1988), which is a regionally persistent coral-stromatoporoid rich packstone. These skeletal units are interpreted to have been deposited during the transgressive open marine portion of the Coralville cycle. Overlying is the Iowa City Member, consisting of pelleted wackestone, packstone, and intraclastic grainstone units. These units create a facies mosaic with two exposure surfaces identified in the Johnson County area. The second "terminal" Coralville exposure surface is of greater thickness and lateral continuity, and is interpreted to have resulted from an offlap of greater magnitude and/or duration. At Mid-River Marina Quarry (STOP 3), the section extends upward to only the first exposure surface, present between beds 19 and 20 of the generalized section (Fig. 2). Detailed stable isotopic data have been collected from the Coralville cycle at this location (see Plocher et al., this report). In general, there is an upward depletion of ^{18}O and ^{13}C in nonluminescent brachiopod calcite as the exposure surface is approached. Iron and manganese concentrations in micrite matrix also decrease upward towards the exposure surface. Units in the upper portion of the cycle, the upper Cou Falls and Iowa City members, are characterized by chemical stabilization in an oxidizing "open-system" meteoric phreatic setting, while units lower in the cycle, the lower Cou Falls, were stabilized in a reducing "closed-system" meteoric phreatic environment.

Take care not to climb on the highwalls as they tend to be unstable in this and other quarries. Please remember while in a large group to be mindful of people at lower levels that might fall prey to dislodged rocks.

STOP 3B - CURTIS BRIDGE QUARRY

Discussion by Orrin W. Plocher

Three generations of north-south parallel highways, following approximately the same route, have been constructed connecting Cedar Rapids with the Iowa City metro area and Interstate 80. In northern Johnson County, these roads cross the Iowa River all in close proximity to the old town site of Curtis, which had a Post Office between the years of 1897 to 1909. Prior to the 1900's, there was only a ferry crossing at this river locality, and the bridge and town of Curtis first appear on the county map in 1900. The opening of the Post Office might be coincident with the construction of the bridge. This first through-road, casually referred to as "old-old 218," is the main north-south road through Shueyville that today dead-ends into the river at the collapsed bridge, which can be seen from this stop. The original road from the south dead-ends at Coralville Lake, at a popular fishing spot and boat ramp, the "Curtis Bridge Recreation Area." The nearly abandoned town site of Curtis is located on the bluffs on the south side of the river between "old-old 218" and the present day I-380. East of Curtis, downriver, is a small quarry adjacent to the reservoir, informally referred to as the Curtis Bridge quarry.

During geologic investigations of the Coralville Lake area, Bunker and Plocher (1987) examined the quarry and recognized thick beds of echinoderm grainstone in the uppermost part of the Rapid Member at the Curtis Bridge Quarry. These beds have been informally referred to as the "Curtis Bridge grainstone" (Plocher, 1987), and the quarry serves as a primary reference section for the unit (Fig. 3). The grainstone at this locality achieves it's greatest known thickness and is the only known location where well developed high-angle crossbeds can be observed. These two features distinguish the grainstone at Curtis Bridge from other locations where it has been recognized. The grainstone at this location is interpreted to have been deposited on the main axis of a shoal complex, which underwent constant winnowing near the end of Rapid deposition (Plocher & Ludvigson, 1989).

The contact between the Little Cedar and Coralville formations is a distinct burrowed disconti-

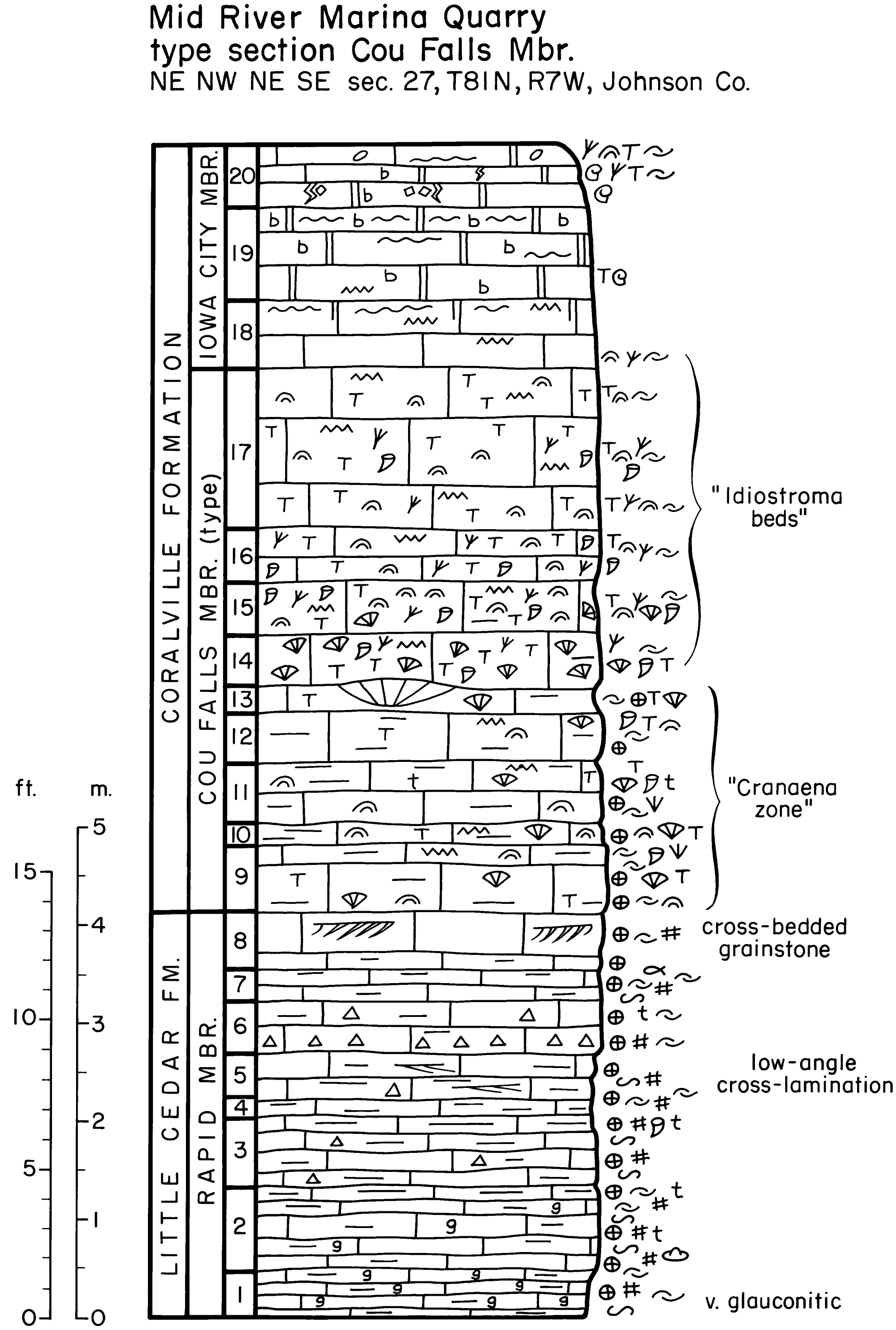

Figure 2. Graphic section of the Mid-River Marina Quarry.

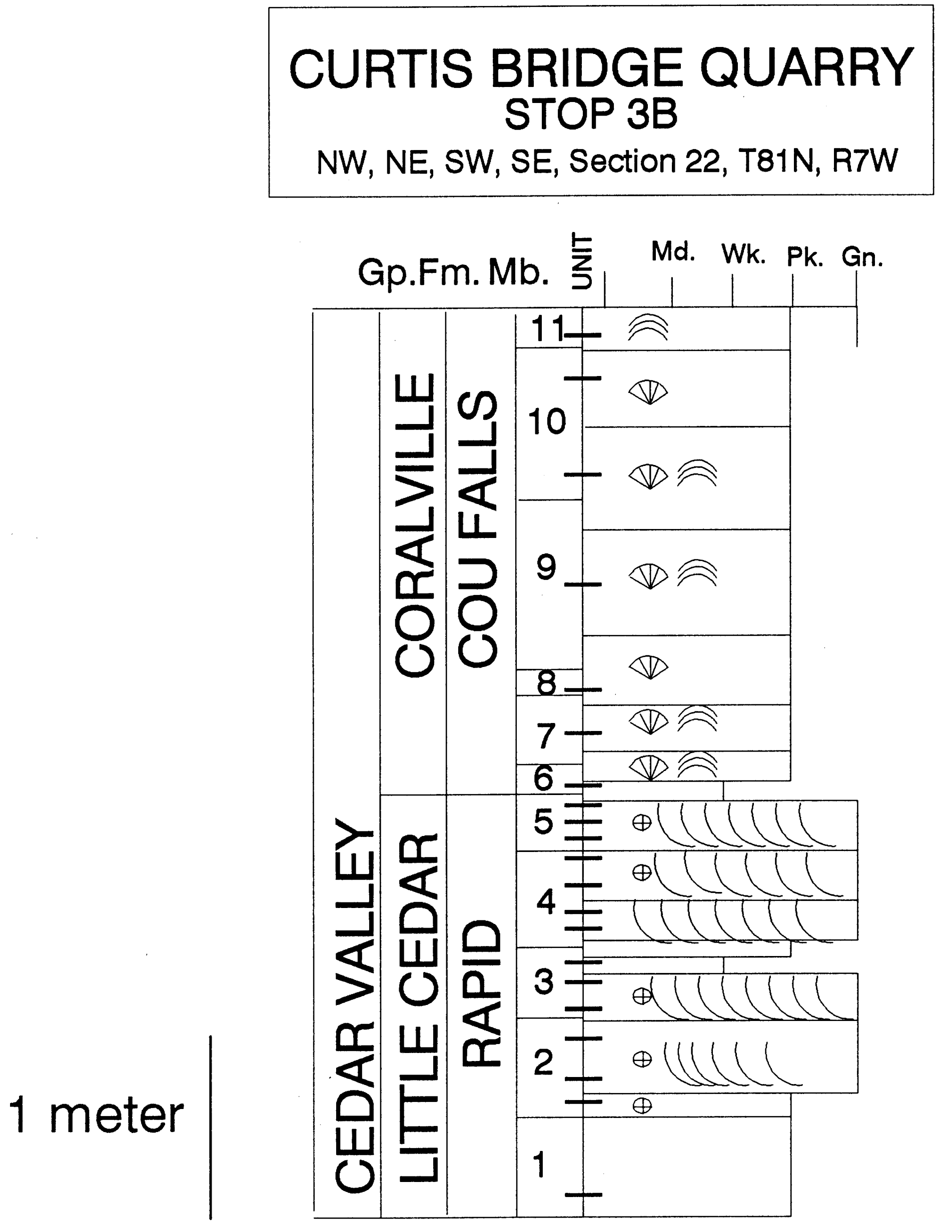

Figure 3. Graphic section of the Curtis Bridge Quarry.

nuity surface. The Cou Falls, the lowest member of the Coralville Formation (Witzke et al., 1988), consists of an abraded coralline-stromatoporoid packstone at this locality. Rounded lithic clasts of the upper-most Rapid Member are found in the basal Coralville Formation at many locations. Many large colonial corals can be found on weathered bedding surfaces in the upper part of the quarry.

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MID RIVER MARINA QUARRY

LOCATION: NE NW NE SE sec. 27, T81N, R7W, Johnson County
Measured by B.J.Witzke & B.J.Bunker, 2/9/1987.

CEDAR VALLEY GROUP
Coralville Formation
Iowa City Member

UNIT 20

Ls., dense, sublithographic to xf.; lower 25 cm highly fractured, microbrecciated in part, laterally less brecciated, scattered birdseye, gastropod noted; upper 38 cm in two beds, fractured in lower part, scattered gastropods (to 6 cm), faintly laminated near base, rubbly-bedded above, intraclastic in part (5 mm clasts), scattered small favositids (1-2 cm), small hemispherical and branching stromatoporoids, scattered *Athyris*; 63 cm.

UNIT 19

Ls., dense, sublithographic, in 3 to 5 beds; lower 25 cm with scattered birdseye, stylolites; upper 70 cm with abundant birdseye laminated fabrics, 25 to 35 cm below top locally fractured to brecciated; 90-96 cm.

UNIT 18

Ls., dense, xf., becomes sublithographic in top 15 cm, scattered to common stylolites throughout; basal 17 cm locally with scattered hemispherical to branching stromatoporoids, rostroconchs noted; scattered small hemispherical stromatoporoids in lower 35 cm; upper 10-17 cm faintly laminated; 66-73 cm.

Cou Falls Member (type section)

UNIT 17

Ls., dominantly a skeletal calcilutite, matrix xf. to sublithographic, irregular fracture bedding, stylolites scattered to common throughout, small calcite fracture fills upward; fossiliferous with small favositids throughout, encrusting to hemispherical stromatoporoids (to 15 cm) scattered to common, branching stromatoporoids (*Idiostroma*) scattered in lower two-thirds, *Athyris* and rostroconchs scattered through, *Cranaena* noted in lower 45 cm, scattered small solitary rugosans in middle part; 1.6 m.

UNIT 16

Ls., fine skeletal calcarenite to calcilutite upward, in 3 beds, biostromal, becomes less coralline upward, denser than below, dark argillaceous partings absent; common small favositids (1-5 cm, some 10 cm), common encrusting and domal stromatoporoids (most 2-8 cm, to 20 cm in upper part), branching stromatoporoids (*Idiostroma*) scattered through, scattered small solitary rugosans (most about 1 cm), brachiopods (*Athyris*, *Cranaena*) and rostroconchs noted; 55 cm.

UNIT 15

Ls., coral-stromatoporoid biostrome in fine skeletal calcarenite matrix, dark argillaceous streaks scattered, rubbly weathered, scattered stylolites; abundant small favositids (2-10 cm), small domal stromatoporoids (to 8 cm), encrusting stromatoporoids over corals, common clusters of solitary rugosans, scattered small *Hexagonaria* (to 4 cm), branching stromatoporoids (*Idiostroma*) scattered (subordinate to corals), indet. brachiopods and crinoid debris noted; 55 cm.

UNIT 14

Ls., coralline biostrome in fine skeletal calcarenite matrix, dark argillaceous streaks scattered, rubbly weathered, faint stylolitic bedding plane at top; packed corals dominated by *Hexagonaria* (to 40 cm) and favositids (to 25 cm), abundant solitary rugosans (to 3-4 cm diameter), brachiopods (atrypids, *Athyris*, *Cranaena*) and rostroconchs noted, branching stromatoporoids (*Idiostroma*) present in top 15 cm; 57 cm.

UNIT 13

Ls., fine skeletal calcarenite to calcilutite, scattered dark argillaceous streaks, in two beds; scattered *Hexagonaria* in lower bed, scattered small hemispherical favositids (to 10 cm) in lower bed; unit replaced laterally by large *Hexagonaria* head 42 cm high x 90 cm wide (draped by unit 14); crinoid debris and brachiopods (*Cranaena*, atrypids) noted; 23 cm.

UNIT 12

Ls., fine skeletal calcarenite, in 1-2 beds, dark argillaceous swirls and partings through, crinoid debris, top marked by stylolite; scattered favositids and small domal stromatolites, scattered *Hexagonaria* (10 cm) and solitary rugosans near top; brachiopods common (*Desquamatia*, *Cranaena*, *Athyris*, *Pentamerella*, others), scattered rostroconchs; 51-54 cm.

UNIT 11

Ls., dominated fine skeletal calcarenite, crinioid debris, some slightly argillaceous calcilutite present, dark shaley streaks scattered through, in 2 beds of subequal thickness, shaley stylolitic parting at top; scattered favositids and solitary rugosans, scattered small hemispherical stromatoporoids (to 6 cm) and thamnoporids, *Hexagonaria* (15 cm) noted near base of top bed; brachiopods scattered to common (*Desquamatia*, *Athyris*, *Cranaena*, others), rostroconchs scattered to common, trilobite debris noted; 62-68 cm.

UNIT 10

Ls., biostromal, fine skeletal calcarenite to argillaceous calcilutite, stylolite with 0.5-3 cm dark gray shale at top, rubbly weathering, irregular at top, irregular shaley partings within; corals (favositids, *Hexagonaria*), hemispherical stromatoporoids (to 15 cm) common; crinoid debris and indet. brachiopods present; 18-25 cm.

UNIT 9

Ls., fine skeletal calcarenite (some skeletal calcilutite in middle part), crinoidal, massive unit except for upper 20-30 cm with wavy argillaceous bands surrounding coral-strom heads, stylolites at top; basal 15 cm with irregular dark argillaceous partings, coral heads (some overturned) to 20 cm (favositids, *Hexagonaria*), hemispherical stromatoporoids, brachiopods, bryozoan and crinoid debris noted; middle 30 cm with scattered to common corals (as above), rostroconchs, brachiopods (especially atrypids); upper 25 cm with common to abundant brachiopods (collections from this interval by Witzke and Bunker summarized by J. Day, this guidebook; *Desquamatia*, *Strophodonta*, etc.), rostroconchs and trilobites common; 70 cm.

Little Cedar Formation
Rapid Member

UNIT 8

Ls., packstone to grainstone; lower 15 cm horizontally bedded packstone with argillaceous partings, dominantly crinoidal, calcilutite-filled horizontal burrows present; upper 45 cm crinoidal grainstone, cross-bedded, in part weathers crumbly, *Megistocrinus* columnals common, cystoid plates and cystodictyonid bryozoans present, brachiopods include *Desquamatia*, *Orthospirifer*, *Tylothyris*, chonetids; upper contact sharp, irregular surface, burrowed in part; 60 cm.

UNIT 7

Ls., interbedded argillaceous calcilutite and calcarenite, dominated by packstone-grainstone, very crinoidal, thinly-bedded shaley interval forms re-entrant at top, calcilutite-filled horizontal burrows present; brachiopods include *Desquamatia*, *Tylothyris*, *Orthospirifer*, *Cyrtina*; small bryozoans, placoderm plate noted; 32 cm.

UNIT 6

Ls., skeletal calcilutite to calcarenite, stringers of calcarenite (packstone), horizontal burrows scattered through, very skeletal in upper part (crinoidal packstone grading to grainstone), interlaminated shaley burrowed calcilutite and calcarenite stringers at top, in 2 beds; prominent laterally continuous chert band 16 cm above base (to 6 cm thick), scattered nodular cherts (silicified packstones in part) above; crinoid debris (including *Megistocrinus*), bryozoans (trepostomes, cystodictyonids), brachiopods common to abundant (*Orthospirifer*, *Desquamatia*, *Tylothyris*, *Cyrtina*, others); 53 cm.

UNIT 5

Ls., dominantly argillaceous sparsely skeletal calcilutite with stringers of skeletal calcarenite increasing upwards, horizontally burrowed, weakly laminated in part with probable low-angle cross-lamination; in 2 subequal beds separated by 2 cm shale re-entrant; lower bed with scattered chert nodules (large nodule near base to 15 cm); upper bed more skeletal, gradational into overlying unit; crinoid debris, trepostome bryozoans, brachiopods (*Tylothyris*, *Cyrtina*, *Orthospirifer*, *Schizophoria*); 46 cm.

UNIT 4

Ls., argillaceous skeletal calcilutite to calcarenite (interlayered argillaceous wackestones and skeletal packstones), numerous shaley partings; crinoid debris, trepostome bryozoans (to 3 cm), whole-shell brachiopods (dominantly *Desquamatia* with *Orthospirifer*, *Cyrtina*); inarticulate brachiopod noted; 18 cm.

UNIT 3

Ls., mixed argillaceous calcilutite to fine skeletal calcarenite, burrowed (calcilutite-filled burrows in calcarenite noted), thin wavy bedded, sharp contact at top; scattered chert nodules (1-10 cm diameter); crinoidal (common *Megistocrinus* columnals), bryozoans, scattered brachiopods (*Pseudoatrypa*, *Schizophoria*); top 15 cm interbedded with very shaley calcilutites, corals (thamnoporid, auloporid, 5 cm diameter solitary rugosan), trepostones, *Melocrinites*, *Orthospirifer*, packstone at top (with *Desquamatia*, *Tylothyris*); 73 cm.

UNIT 2

Ls., argillaceous skeletal calcilutite, calcarenitic stringers scattered (fewer than below), horizontal burrows, glauconitic in part (less than below), thin wavy partings, in 2 beds (upper bed 28 cm, less brachiopod-rich, more finely skeletal); shaley re-entrant at top with large (2 cm diameter) calcarenite-filled burrows; crinoid debris (including *Megistocrinus*), bryozoans (cystodictyonids and encrusting trepostomes), scattered pachyporid corals, common brachiopods (*Schizophoria*, *Pseudoatrypa*, *Tylothyris*, *Desquamatia*, *Orthospirifer*, *Eosyringothyris*, *Schuchertella*, *Cupulorostrum*, others), tentaculites and bivalves noted; 85 cm.

UNIT 1

Ls., argillaceous skeletal calcilutite with burrowed skeletal calcarenite stringers, thin wavy bedded, very glauconitic (glauconite pellets to 2 mm diameter), unit is recessive, top surface calcarenitic; crinoid debris, bryozoans (including encrusting forms), brachiopods (*Orthospirifer*, *Tylothyris*, others), tentaculites; 50 cm.

CURTIS BRIDGE QUARRY

LOCATION: NW•NE•SW•SE• Section 22, T81N, R7W
Measured by O.W. Plocher, 1989

CEDAR VALLEY GROUP
Coralville Formation
Cou Falls Member

UNIT 11

Fine-grained coralline-rich calcarenite; abundant corals and stromatoporoids, forms recessive rubble unit, *Hexagonaria*, *Favosites*, solitary rugosans, hemispherical stromatoporoids, abundant *Idiostroma*, brachiopods; 20 cm.

UNIT 10

Fine-grained skeletal calcarenite; abundant corals, massive wavy bedded, scattered brachiopods, *Favosites*, *Hexagonaria*, massive stromatoporoids, solitary rugosans; 85 cm.

UNIT 9

Fine-grained skeletal calcarenite; abundant corals and stromatoporoids, massive wavy bedded, stylolites and large calcite void fills, *Favosites*, *Hexagonaria*, solitary rugosans, scattered brachiopods, massive stromatoporoids; 95 cm.

UNIT 8

Argillaceous organic-rich fine-grained skeletal calcarenite; recessive unit, scattered brachiopods; 15 cm.

UNIT 7

Medium-grained skeletal calcarenite; wavy bedded, scattered brachiopods and echinoderm debris, *Favosites*, *Hexagonaria*, solitary rugosans, rostroconchs, trilobites; 40 cm.

UNIT 6

Coarse-grained skeletal calcarenite; abundant corals, scattered brachiopods, echinoderm debris, *Hexagonaria*, solitary rugosans; 15 cm.

Little Cedar Formation
Rapid Member

UNIT 5

Mixed skeletal calcilutite to fine-grained calcarenite; wavy bedded, stylolitic, echinoderm and brachiopod debris; 30 cm.

UNIT 4

Coarse-grained echinoderm calcarenite; base is very argillaceous, prominent cross-beds with dip angles up to 40°, scattered brachiopod debris; 55 cm.

UNIT 3

Burrowed medium- to fine-grained echinoderm calcarenite; planar cross-beds to wavy bedded, scattered brachiopods; 40 cm.

UNIT 2

Medium- to coarse-grained echinoderm calcarenite, wavy bedded, whole brachiopods, limonite replacement of some grains; 55 cm.

UNIT 1

Laminated sparsely fossiliferous calcilutite; scattered fine-grained calcarenite, small scale horizontal and vertical burrows present; 55 cm.

STOP 4. CONKLIN QUARRY

Discussion by Bill J. Bunker and Brian J. Witzke

DISCUSSION. Early quarry operations at the site of the present day Conklin Quarry can be traced back to at least the end of the 19th century. Calvin (1897) noted a quarry on the geologic map of Johnson County, and refers to kiln operations by Mr. Linder at this location. Additional comments regarding quarry operations at this site are also noted by Beyer and Wright (1914) who referred to "... the old railway quarry on the west bank of the river north of Coralville ... These beds were formerly worked by the Rock Island Railway Company for crushed stone. A switch was extended to the quarry and a large amount of railway ballast produced. ..."

Owen (1852) termed the Middle Devonian carbonate sequence of eastern Iowa the "limestones of Cedar Valley," and McGee (1891) formally designated this interval the "Cedar Valley Limestone". However, no type locality for the Cedar Valley Limestone was ever designated. Bunker et al. (1985) and Witzke et al. (1988) proposed the primary reference section at Conklin Quarry (Figs. 1, 2). Stainbrook (1941) also designated Conklin Quarry as the Coralville type section. Additionally, exposures of the Rapid Member occur upstream approximately 0.2-0.5 miles (NW NW SW secs. 34 & NE SE 32, R6W, T80N) from the easternmost workings of the present day Conklin Quarry. These exposures represent the type section of the Rapid (Stainbrook, 1941a). However, only the uppermost beds (*waterlooensis* Zone, with the biostrome beds at river level) are present at this locality. Hence, a standard reference section for the Rapid Member is herein proposed for the Conklin Quarry pit, where the member is exposed in its entirety (Figs. 1, 2).

Conklin Quarry has served as a primary site for many paleontologic investigations over the past several decades. Studies involving calcareous foraminifera (Kettenbrink & Toomey, 1975), corals (Pitrat, 1962; Zawistowski, 1971), crinoids (Calhoun, 1983), chitinozoans (Dunn, 1959), conodonts (Klapper & Ziegler, 1967), trilobites (Hickerson, 1989, this guidebook), miospores (Klug, 1990, and this guidebook), and brachiopods (Stainbrook, 1938-1943, references listed in Day, this guidebook) have been undertaken. Additional studies have focused on depositional environments (Kettenbrink, 1973; Mitchell, 1977), mineralization (Garvin, 1984; Garvin & Ludvigson, 1988), and paleomagnetism (Parse & Plumley, this guidebook). Conklin Quarry also displays one of the thickest, most complete sections of pre-Illinoian Quaternary deposits in the Midwest (Hallberg et al., 1984).

Shallow subtidal and peritidal deposits, which reflect transgressive-regressive (T-R) cycles of deposition characterize the strata exposed at Conklin Quarry. Exposed in the lowermost portions of the pit area are units of the Wapsipinicon Group (Fig. 1). The most prominent lithology visible are the extensive breccias in the Davenport Member, which are considered to be the result of dissolution of widespread gypsum/anhydrite layers (see Bunker & Witzke, this guidebook). Upward propagating small-scale fractures, faults, and folds through the Cedar Valley Group are considered to be the result of evaporite dissolution and collapse contemporaneous with Cedar Valley deposition. Although the contact with the overlying Little Cedar Formation marks a regionally widespread T-R boundary, the relationships observed at Conklin Quarry are diffuse as a result of the extensive brecciation and stratigraphic leakage at this boundary position.

The Solon Member reflects a pronounced return to shallow subtidal environments, particularly noted by the abundance of fossils. The Solon has been subdivided into two subunits (Stainbrook, 1941a), the lower "*independensis* zone" and the upper "*profunda* beds" (Fig. 1). A sharp lithic/color break denotes the Rapid and Solon contact. While the underlying Solon lithologies are characterized by yellow brown calcarenites, the Rapid is characterized by light blue-grey argillaceous calcilutites. Stainbrook (1941) subdivided the Rapid into three distinct paleo-zones: 1) "*bellula* zone", 2) "*Pentamerella* zone", and 3) "*waterlooensis* zone" (Figs. 1, 2), which are all widespread in the east-central Iowa area. A regionally widespread biostromal unit occurs at the top of the "*Pentamerella* zone", which can be traced from northwest Illinois and Scott County, Iowa into north-central Iowa. The "*waterlooensis* zone" is characterized by prominent chert and glauconite, crinoidal

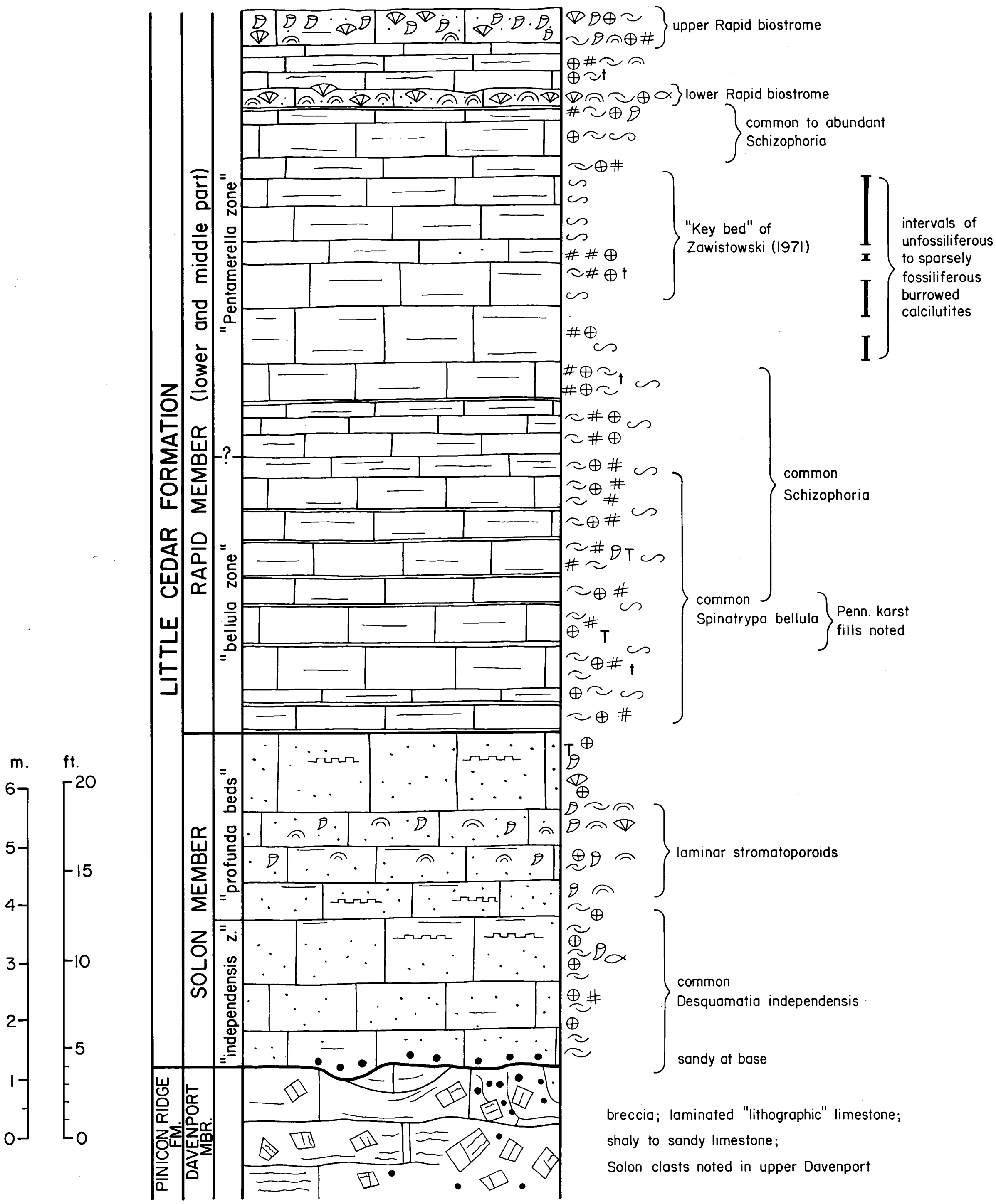

Figure 1. Lower portion of the Devonian stratigraphic sequence in the main pit area, Conklin Quarry.

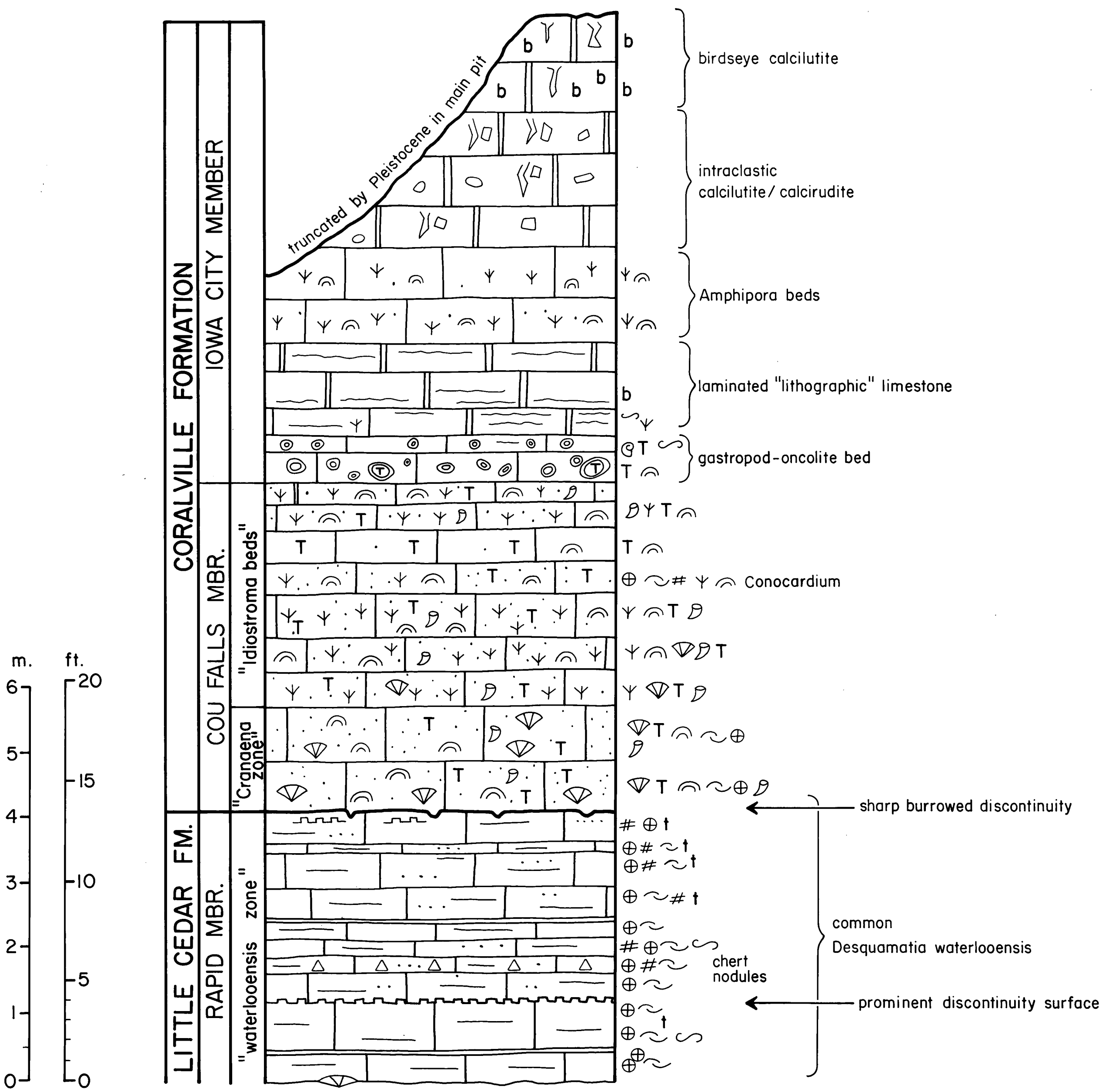

Figure 2. Upper portion of the Devonian stratigraphic sequence in the main pit area, Conklin Quarry.

wackestone-packstone beds locally weather red in outcrop. Hardgrounds are noted within the upper Rapid, and the contact with the overlying Coralville Formation is a widespread discontinuity surface; calcarenites of the Cou Falls Member infill vertical burrows along this surface which locally penetrate up to 30 cm into upper Rapid strata.

Conodont ranges within the Cedar Valley Group of Conklin Quarry and the Johnson County area are summarized on Figure 3. Data was derived primarily from Klug's (1990) sampling of the Conklin Quarry section, supplemented with additional collections within the county by Rogers (1990), Klapper and Ziegler (1967), and the stop leaders. The lower Solon Member contains a fauna assignable to the Middle *varcus* Zone, including *P. varcus, P. ansatus, P. linguiformis linguiformis,* and *O. semialternans*. Klug (1990) also recorded *P. l. klapperi* and *P. l. weddigei* from these strata. Conodont abundance drops off significantly in the upper Solon (Fig. 3), and the position of the Upper *varcus* Zone remains unclear. Conodont collections from the upper strata at the type Solon quarry are reported to contain *S. wittekindti* (Klapper & Ziegler, 1967, p. 80), but the stratigraphic assignment of these samples to the upper Solon needs to be checked. At Conklin Quarry, *S. wittekindti* is first noted at the base of the overlying Rapid Member.

The Rapid Member at Conklin Quarry contains an abundant condont fauna, with the highest diversity noted in the lower strata. The base of the *hermanni* Zone is marked at or near the base of the Rapid, where first occurrences of *S. wittekindti, P. limitaris,* and *I. expansus* are noted. Of special interest is the overlap of *P. varcus* with these species in the basal 2 m of the Rapid, suggesting that the range of *P. varcus* extends into the Lower *hermanni* Zone. The position of the Upper *hermanni* Zone is not known with certainty in Johnson County. However, occurrences of *S. percacutus* in Scott County, Iowa, project into the Conklin Quarry section within the "*bellula*" beds, suggesting that the base of the Upper *hermanni* Zone should be drawn within the lower Rapid Member. *I. l. latericrescens* ranges upward to the position of the Rapid biostromes, where the first occurrences of *I. subterminus* are noted. At a lower stratigraphic position similar to *I. difficilis* but with elevated posterior middle row denticles, a feature close to *I. subterminus*, occurs in the upper "*bellula*" beds (Klug, 1990, p. 70); these are labelled *I.* cf. *subterminus* on Figure 3.

The upper Rapid Member (including the biostromes and the "*waterlooensis* zone") is assigned to the Lower *subterminus* Fauna, which has been suggested to equate with part (or all) of the *disparilis* Zone of the standard zonation (Witzke et al., 1985). Conodont samples from a phosphate unit near the base of the biostromes are exceptionally productive.

The Coralville Formation represents a major T-R cycle (Cycle IIa-3 of Witzke et al., 1988; see fig. 6 of Bunker & Witzke, this guidebook) with upward shallowing conditions evident within the quarry walls. The lower Cou Falls Member (Fig. 2) is characterized by fossiliferous fine-grained calcarenite (primarily an abraded-grain packstone) with coral and stromatoporoid biostromes through much of the sequence (Kettenbrink, 1973). Thin shaly and dark carbonaceous partings occur in the lower half. Stainbrook (1941) and Kettenbrink (1973) subdivided the lower Coralville sequence in Johnson County (Cou Falls Member) into two faunal intervals, the lower "*Cranaena* zone" and the upper "*Idiostroma* beds" (Fig. 2). The "*Cranaena* zone" contains prominent coralline biostromes dominated by colonial (*Hexagonaria*) and solitary rugosans (Pitrat, 1962), favositids, and massive stromatoporoids. Brachiopods are common in some beds (Day, 1988); *Seratrypa, Pseudoatrypa, Cranaena, Pholidostrophia,* and *Pentamerella* generally dominate. The "*Idiostroma* beds" are characterized by biostromal strata containing branching ("*Idiostroma*") and massive stromatoporoids, colonial (*Hexagonaria*) and solitary rugosans, and favositids.

Conodonts of the Cou Falls Member are sparse, but include *Icriodus subterminus, Mehlina gradata, Polygnathus angustidiscus* and other undescribed species of *Polygnathus* (*P.* n sp. A, Rogers, 1990; and collections by the authors) (Fig. 3); these indicate assignment to the Upper *subterminus* Fauna (Witzke et al., 1988; Rogers, 1990).

The Cou Falls Member is conformably overlain by the Iowa City Member in the quarry area (Fig. 2). The Iowa City Member is characterized by a diverse assemblage of lithologies that commonly share significant lateral facies variations over short distances. The member includes the following lithologies: 1) laminated and pelleted calcilutites, commonly "sublithographic" with "birdseye"

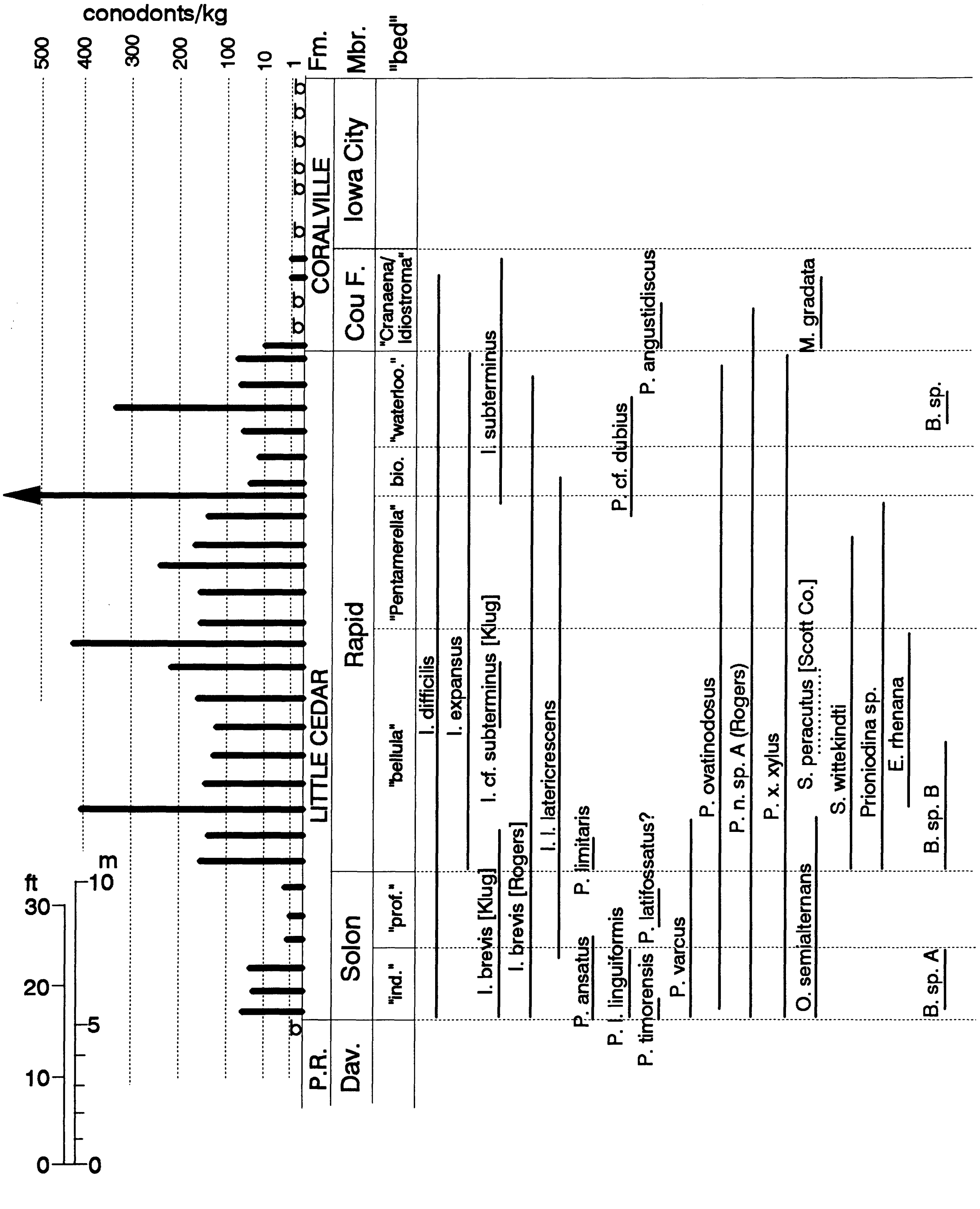

Figure 3. Conodont ranges for Little Cedar and Coralville formations in Johnson County, Iowa,, primarily from Klug (1990), Conklin Quarry samples, supplemented by data in Rogers (1990), Klapper and Ziegler (1967), and oauthors collections. Conodont abundance data largely after Klug (1990), Conklin Quarry, supplemented by data in Rogers (1990), and authors collections. Abbreviations : I. = *Icriodus*; P. = *Polygnathus*; O. = *Ozarkodina*;; S. = *Schmidtognathus*; m. = *Mehlina*; E. = *Elsonella*; B. = *Belodella*; P.R. - Pinicon Ridge; Dav. - Davenport; "ind. - *independensis*; "prof. - *profunda*; bio - -biostrome; "waterloo." - *waterlooensis*; Cou F. - Cou Falls; b - barren

voids and stylolites; 2) pelleted calcilutites with scattered to abundant corals and/or stromatoporoids; 3) intraclastic, brecciated, or onocolitic limestones; and 4) some thin shales, in part carbonaceous. Mudcracks and vadose pisoliths are noted in some beds, and erosional surfaces occur locally within the sequence. The Iowa City Member is absent 12 km to the southeast, where the entire Coralville is represented by fossiliferous calcarentites of the Cou Falls Member. The edge of the Iowa City Member trends south-southwest from the type area, and the member is absent in southeastern Iowa and adjacent parts of northeastern Missouri and western Illinois (Witzke et al., 1988). Conodonts have not been recovered from the Iowa City Member.

PLEASE WEAR YOUR HARDHATS AND USE CAUTION AROUND THE HIGH WALL AREAS.

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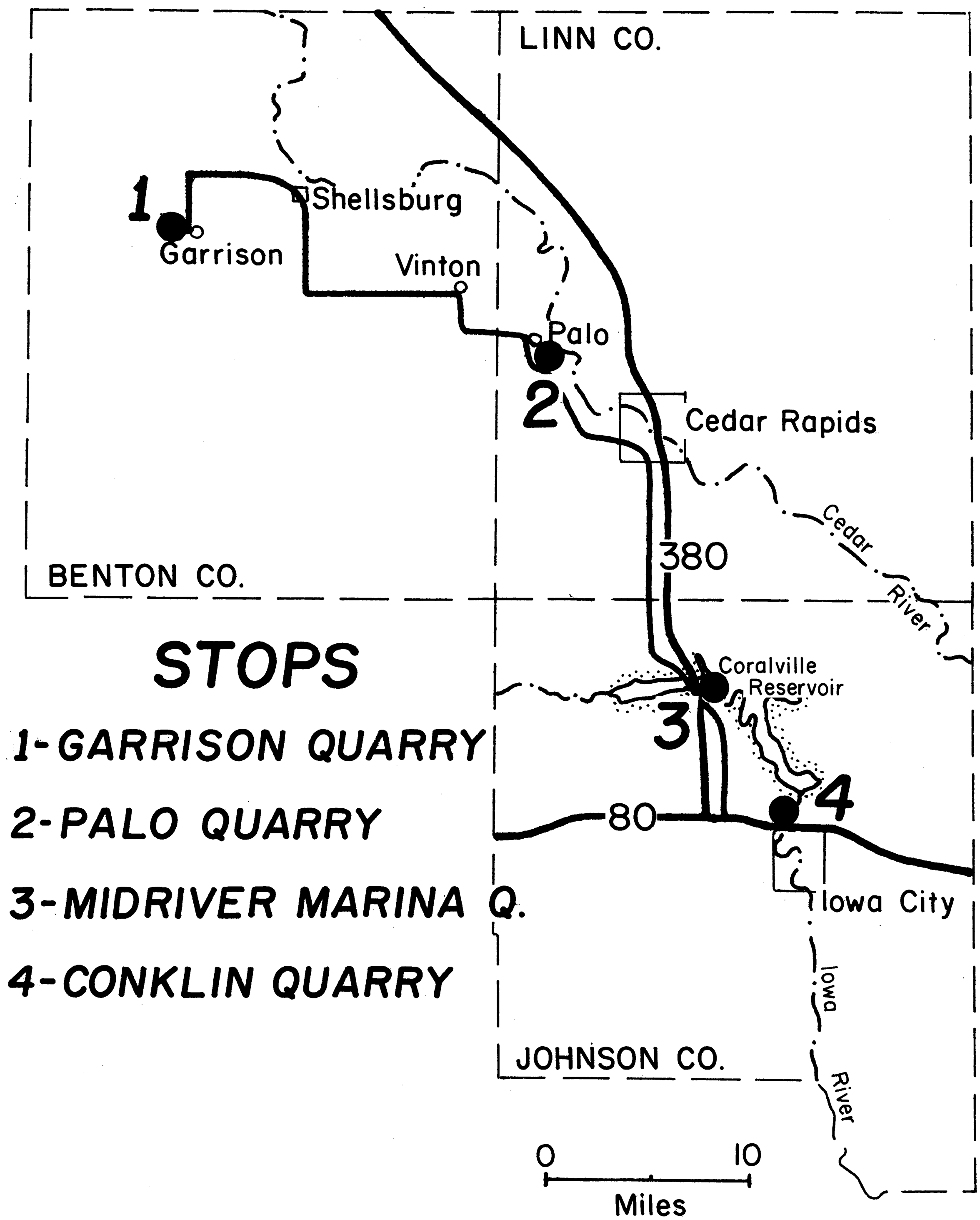
Iowa Department of Natural Resources
Energy and Geological Resources Division
Geological Survey Bureau
109 Trowbridge Hall
Iowa City, Iowa 52242-1319
(319) 335-1575


LINN CO.
1
Shellsburg
Garrison
Vinton
Palo
2
Cedar Rapids
Cedar
River
380
BENTON CO.
STOPS
1-GARRISON QUARRY
2-PALO QUARRY
3-MIDRIVER MARINA Q.
4-CONKLIN QUARRY
Coralville
Reservoir
3
4
80
Iowa City
Iowa
River
JOHNSON CO.
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