GEOLOGIC RECONNAISSANCE of the CORALVILLE LAKE AREA

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Cover: Professor Samuel Calvin and his wife with students at the type State Quarry, April 22, 1899. Photograph courtesy of The University of Iowa, Department of Geology (Calvin Photo Collection).

A GEOLOGICAL RECONNAISSANCE OF THE CORALVILLE LAKE AREA

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INTRODUCTION

Although a number of organized geological field excursions have visited Devonian, Pennsylvanian, and Quaternary exposures in the Iowa City area [see Ruhe, 1968; Glenister & Rexroad, 1968; Heckel et al., 1975; Bunker & Hallberg (eds.), 1984; and Witzke (ed.), 1984], this is the first formal trip to focus primarily on the Coralville Lake area. A discussion of the Quaternary history of the Iowa River valley in the Coralville Lake area can be found in Bettis (this guidebook). Nations and Ludvigson (this guidebook) discuss the palynology and diagenetic aspects of the Pennsylvanian. Because the primary emphasis of this field trip will focus upon the late Middle Devonian, a brief summary of the stratigraphic and structural setting of these strata follows. To further acquaint the field trip participant(s) with the Middle Devonian rocks of the Coralville Lake area, a series of articles within this guidebook will discuss various aspects of the stratigraphy (Plocher & Ludvigson; Bunker & Witzke), biostratigraphy (Hickerson; Day), diagenesis (Plocher & Ludvigson; Ludvigson), and paleomagnetism (Parse & Plumley) of the Cedar Valley Group.

DEVONIAN STRATIGRAPHIC FRAMEWORK AND STRUCTURAL SETTING

Stratigraphy

Stratigraphic and biostratigraphic studies of the Middle and lower Upper Devonian rocks in Iowa during the 1980's has resulted in the introduction of a new stratigraphic framework for these units. A brief summary of the historical development of stratigraphic terminology is illustrated in Figure 1. 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 by Witzke et al. (1988), and includes four formations, each corresponding to a major transgressive-regressive 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. The stratigraphic framework of the Cedar Valley Group and its constituent subunits is summarized in Figure 2. More complete discussions of the history of stratigraphic nomenclature for the Cedar Valley Limestone can be found in Kettenbrink (1972) and Witzke et al. (1988).

No type locality for the Cedar Valley Limestone has ever been designated, but a primary reference section at Conklin Quarry near Iowa City has been proposed (Bunker et al., 1985), and representative sections are graphically illustrated in Figure 3 for the reader's orientation.

Regional Structure

Devonian strata in Iowa and the surrounding region unconformably overlie a paleotopographic surface with moderate to high relief which developed on Ordovician and Silurian strata (Fig. 4; Bunker et al., 1983). Upper Devonian rocks overstep onto the Precambrian surface adjacent to the Sioux Ridge in extreme northwestern Iowa (Fig. 4). Devonian strata in the central Midcontinent region are bounded to the north-northwest by the Transcontinental Arch (including the Sioux Ridge), to the west by the

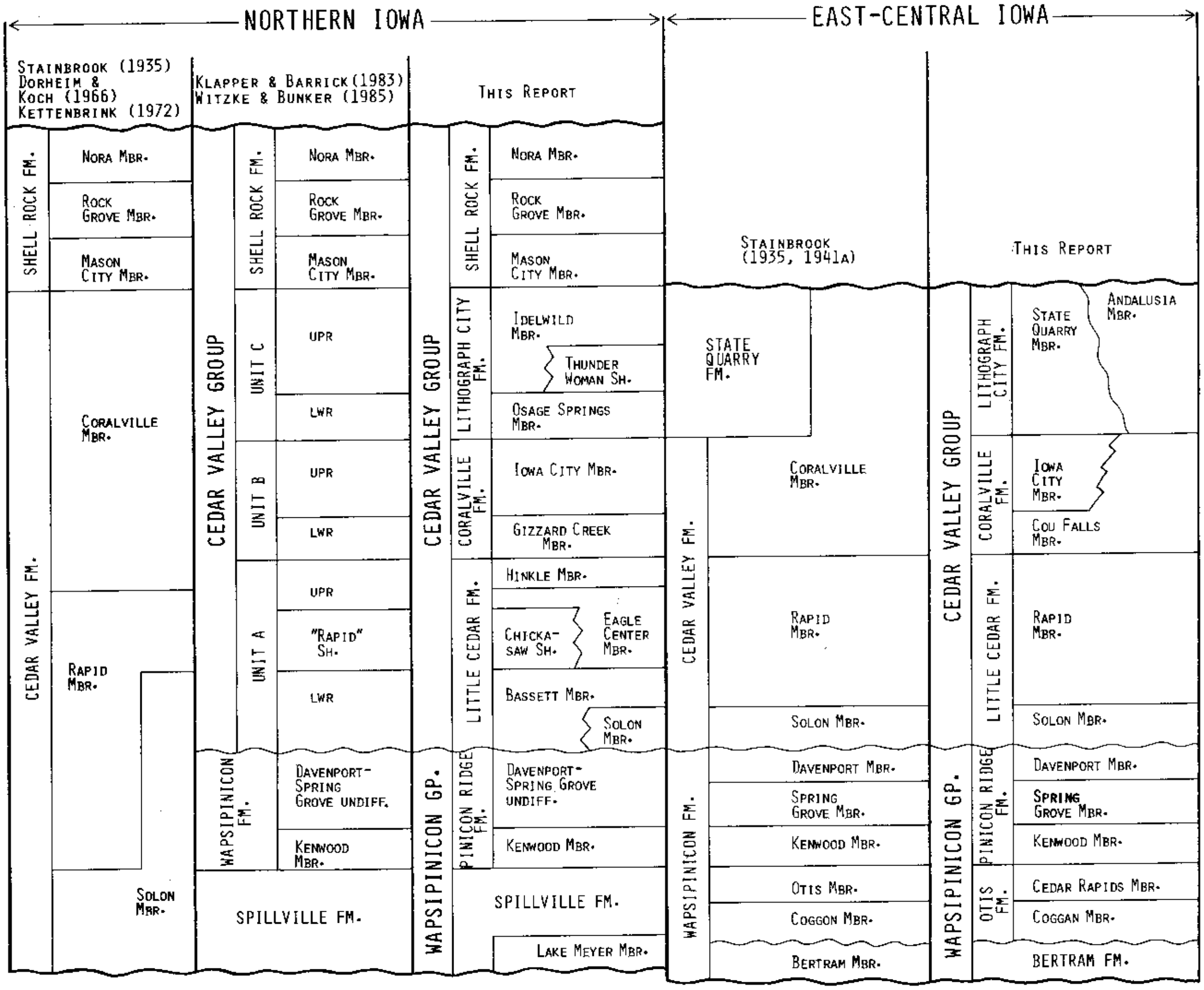


Figure 1. Historical summary of the stratigraphic nomenclature of the Middle and lower Upper Devonian rocks of northern and east-central Iowa (from Witzke et al., 1988).

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. 4, 5).

The East-Central Iowa and North Kansas basins (Fig. 4) are primarily Silurian features, but persisted as structural depressions during the initial stages of Middle Devonian deposition in the region. Late Middle and lower Upper Devonian strata thicken markedly toward central and northern Iowa, where the thickest sequences of Devonian rocks in the region are preserved (to 230 m). Total Devonian isopachs delineate this area as a stratigraphic basin (Fig. 5; i.e. Iowa Basin of Witzke et al., 1988).

The Iowa Basin encompassed an area of extensive shallow-marine, restricted marine, tidal-flat, and evaporite deposition during the Middle and Late 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 portion of the Illinois Basin (see discussions of the Little Cedar Formation in Plocher & Ludvigson and of the Coralville Formation in Bunker & Witzke, this guidebook).

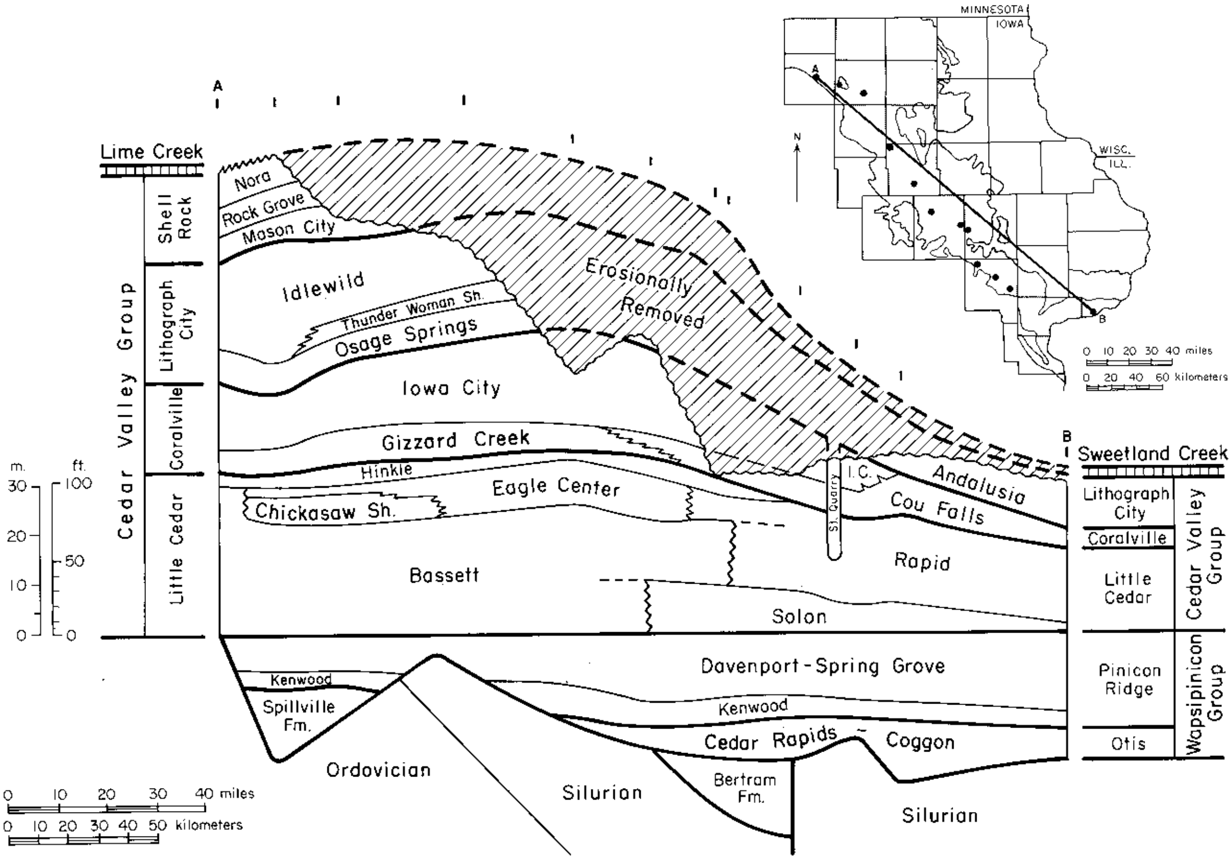


Figure 2. Generalized stratigraphic cross-section from north-central to extreme east-central Iowa, showing interpreted stratigraphic relationships of the various units of the Wapsipinicon and Cedar Valley groups (from Witzke et al., 1988).

Local Structure

Geological investigations of the Coralville Lake area during the mid-1980's (Bunker & Plocher, 1986, 1987) generated a data set that was utilized in the construction of a bedrock geologic and structure map (Fig. 6) of the Lake area. Structure contour mapping was completed on top of the Wapsipinicon Group, as reflected in Figure 6, and depicts a series of northeast to southwest trending anticlines and synclines. The prominent anticline noted through the central area of the Lake has been termed the Twin View Heights Anticline, based upon the exposures of Wapsipinicon Group strata exposed along the Lake front below the community of Twin View Heights. The adjacent syncline along the southwestern flank of the anticline is particularly interesting in that strata of the Lithograph City (State Quarry and Andalusia members) and Lime Creek ("North Liberty" beds of Müller & Müller, 1957) formations have been preserved. The preservation of the State Quarry Member is fortuitous, both because of its structural setting as well as its development within a paleotopographic depression (see Bunker & Witzke, this guidebook, for a discussion of these relationships). Minor faults and folds have not been noted on the geologic map, due to scale, but the field trip participant(s) can observe small scale faulting at STOPS 1 and 3.

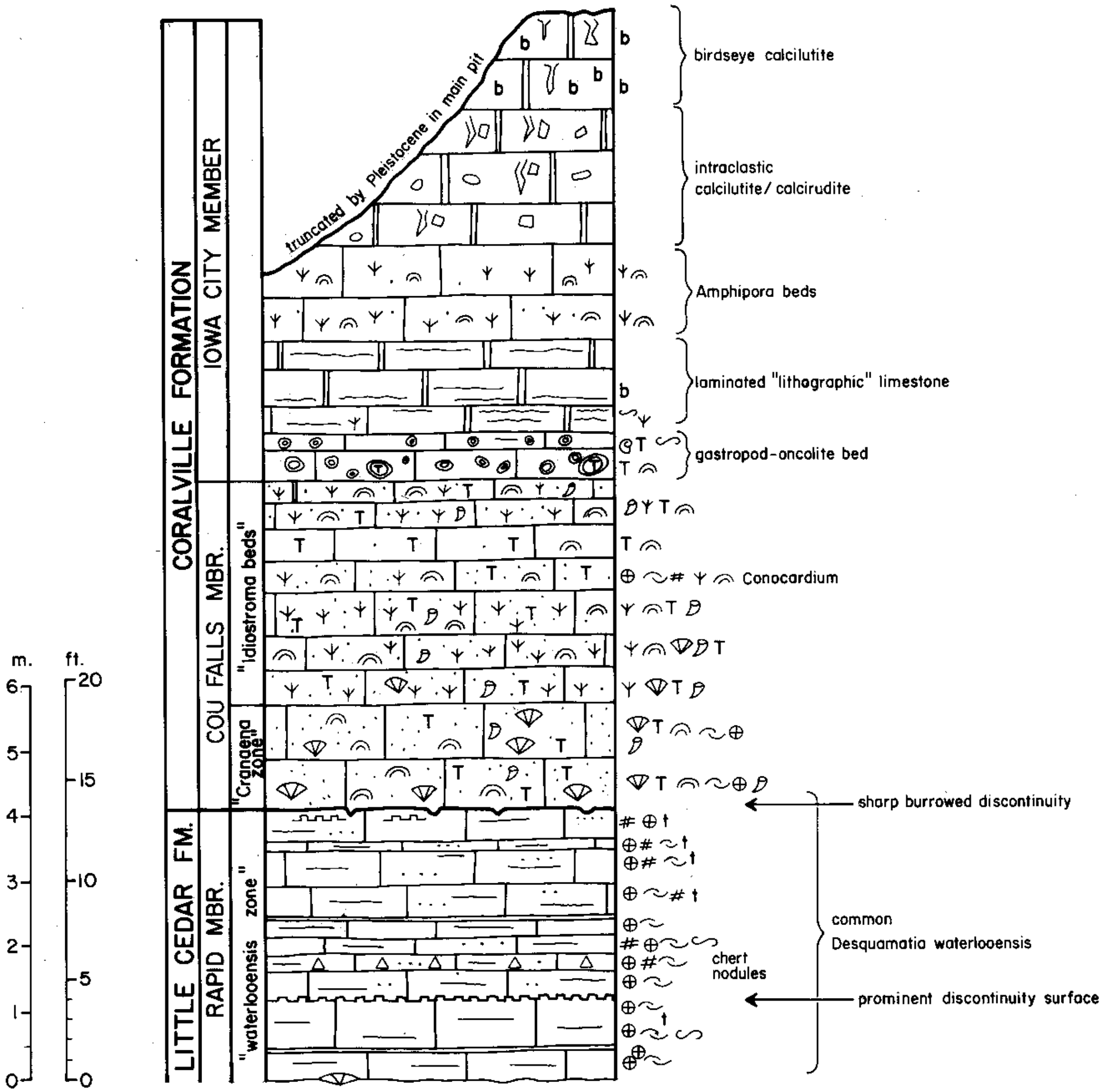
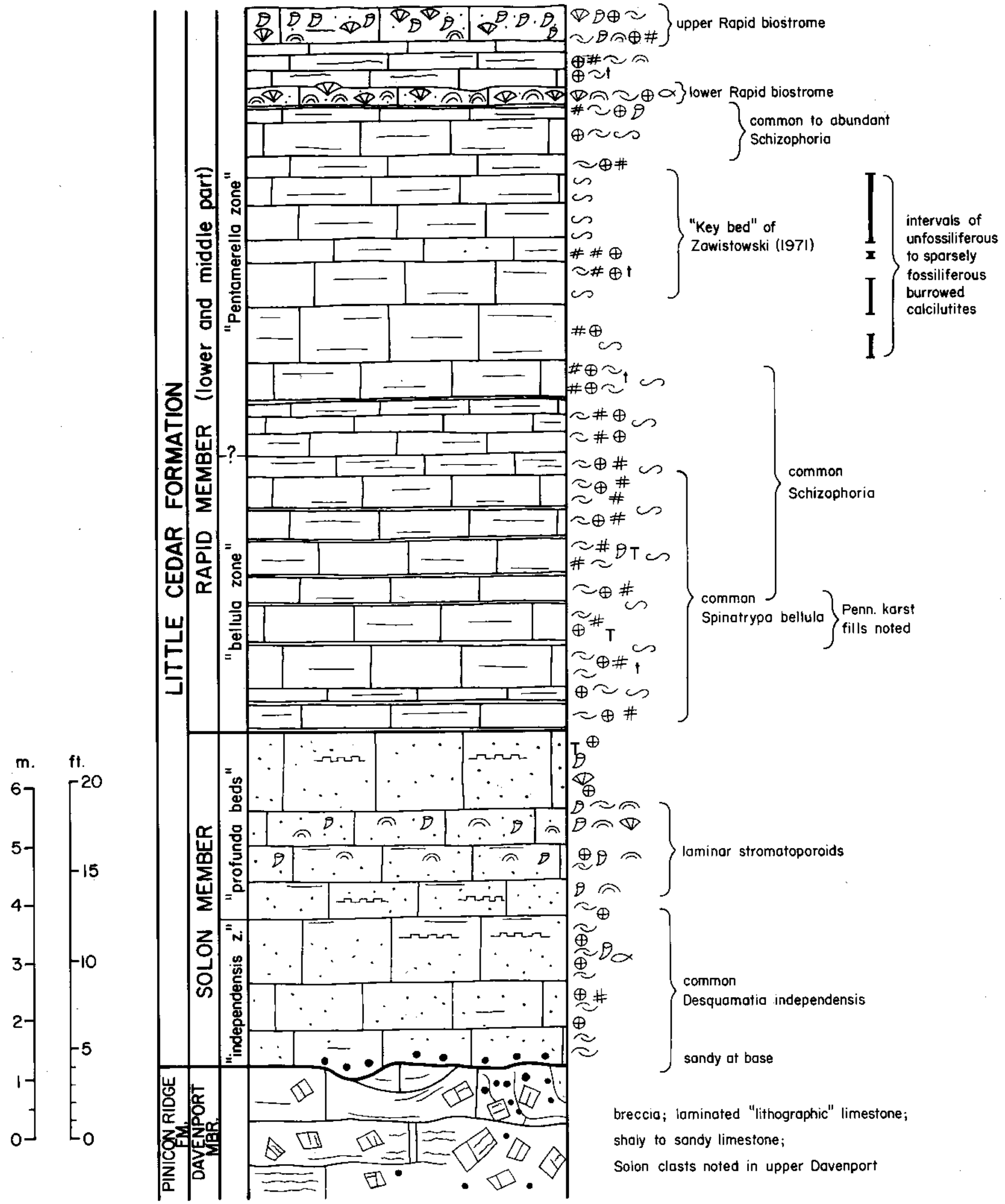


Figure 3. Representative graphic sections of the primary reference section of the Cedar Valley Group, Conklin Quarry, Johnson County, Iowa. (modified from Witzke & Bunker, 1984).


LITTLE CEDAR FORMATION
RAPID MEMBER (lower and middle part)
"Pentamerella zone"
?
"bellula zone"
SOLON MEMBER
"profunda beds"
"independensis z."
PINICON RIDGE FM.
DAVENPORT MBR.
m.
ft.
6
5
4
3
2
1
0
20
15
10
5
0
upper Rapid biostrome
lower Rapid biostrome
common to abundant Schizophoria
"Key bed" of Zawistowski (1971)
intervals of unfossiliferous to sparsely fossiliferous burrowed calcilutites
common Schizophoria
common Spinatrypa bellula
Penn. karst fills noted
laminar stromatoporoids
common Desquamatia independensis
sandy at base
breccia; laminated "lithographic" limestone;
shaly to sandy limestone;
Solon clasts noted in upper Davenport

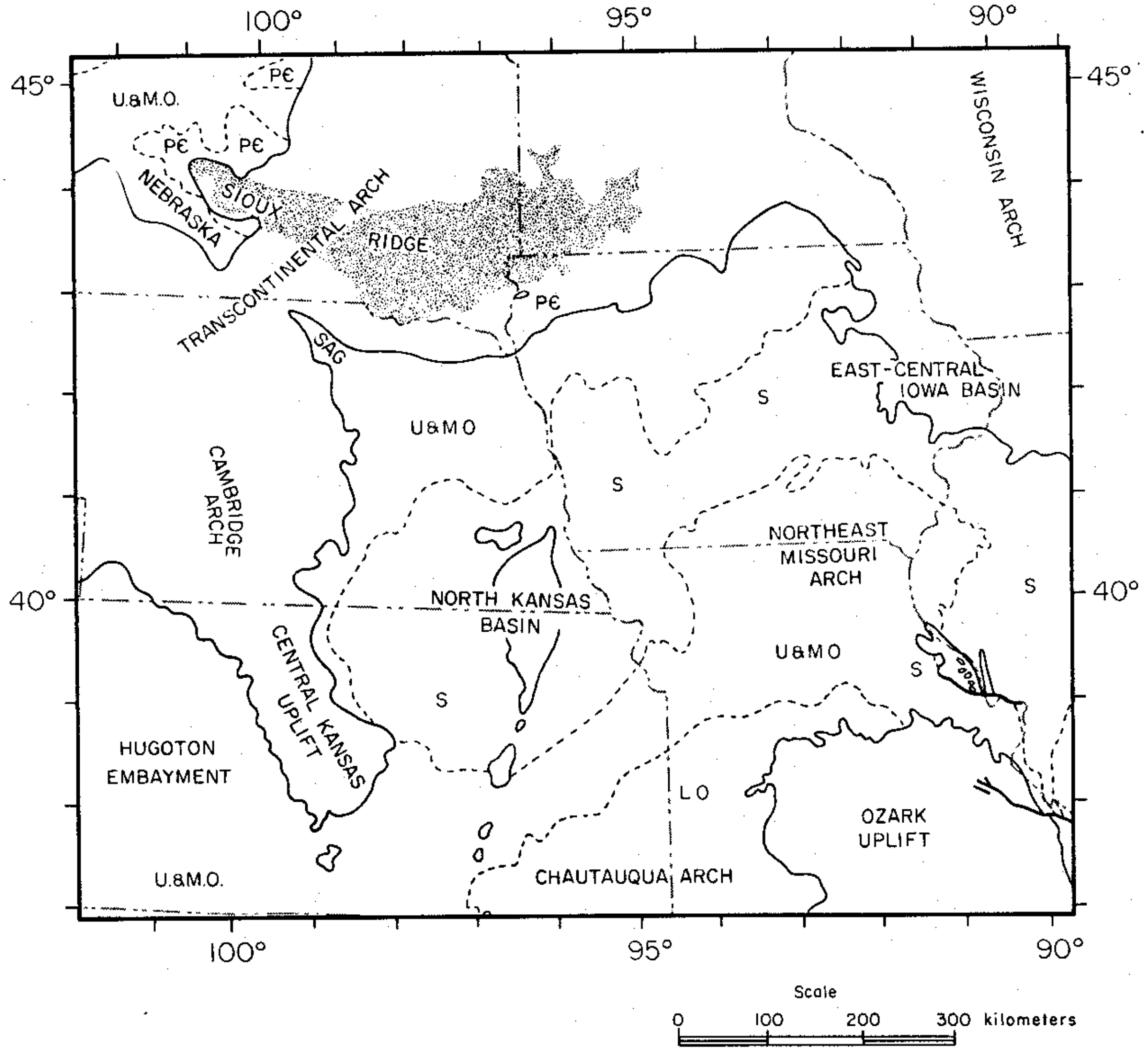


Figure 4. Paleogeologic map of the pre-Kaskaskia sequence of the central Midcontinent region, U.S. (from Bunker et al., 1988).

ACKNOWLEDGMENTS

The numerous authors within this guidebook extend their appreciation and thanks to the U.S. Army Corps of Engineers and the Iowa Department of Natural Resources (Lake Macbride State Park), and the University of Iowa (Recreational Services, Macbride Nature Recreation Area) for permission to access and collect many of the interesting bedrock and Quaternary exposures in the Coralville Lake and Lake Macbride area.

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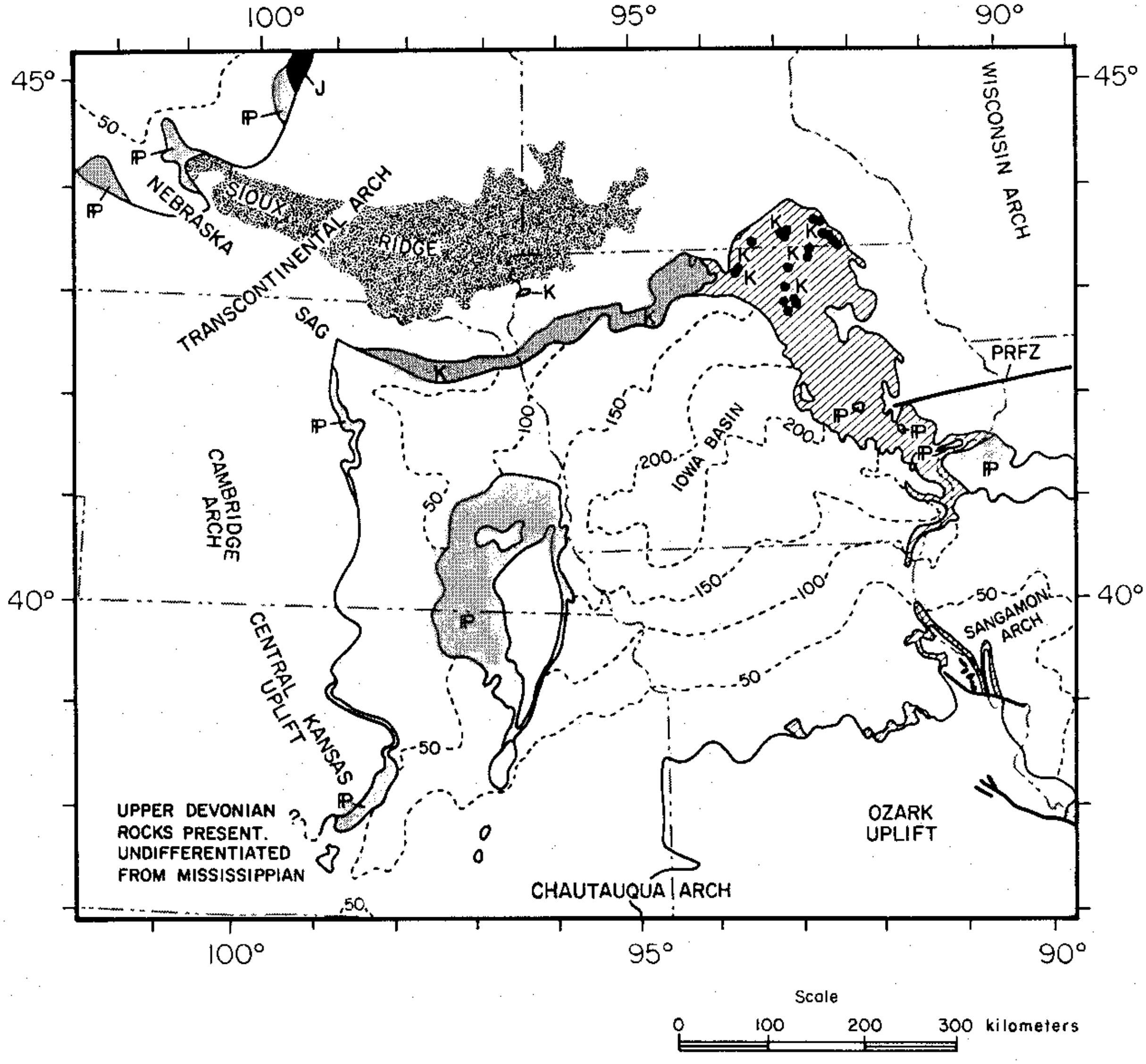

Figure 5. Isopach map of the Devonian of the central Midcontinent region, U.S. (from Bunker et al., 1988).

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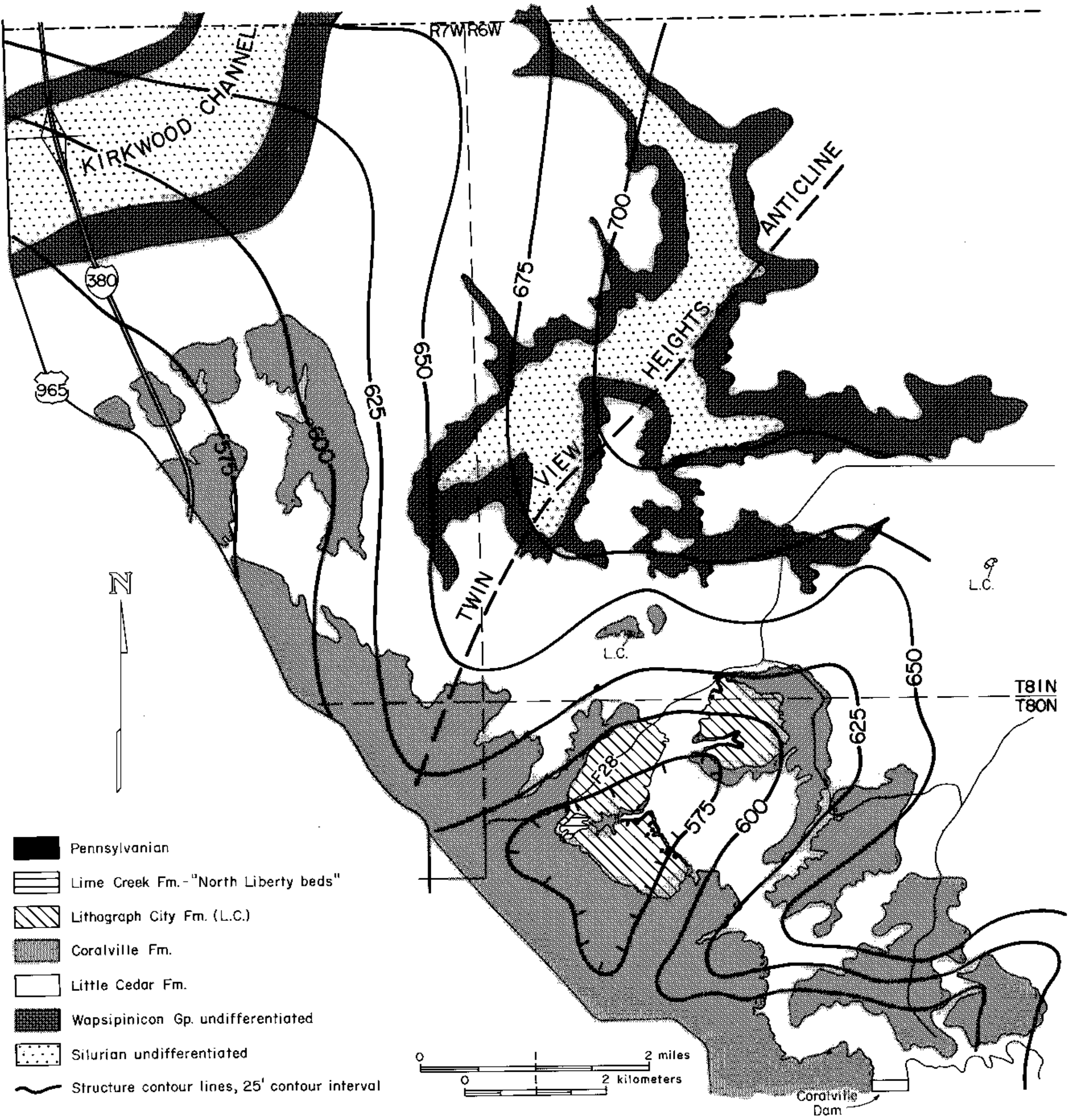

Figure 6. Geologic and structure contour map of the Coralville Lake area. Structure contour interval is on top of the Wapsipinicon Group. (modified from Bunker & Plocher, 1987).

FACIES OF THE UPPER LITTLE CEDAR FORMATION

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INTRODUCTION

The Little Cedar Formation is one of four major transgressive-regressive units in the Cedar Valley Group (Witzke et al., 1988). This report discusses depositional and diagenetic relationships in the upper part of the Little Cedar Formation; the Rapid, Eagle Center, and Hinkle members, all above a biostromal interval in the unit. A general onshore-offshore trend along the outcrop belt from north-central Iowa to southeastern Iowa has been previously established using regional lithic trends (ibid.). All units in the Cedar Valley Group exhibit shallower-water depositional facies in northern and central Iowa than in southeastern Iowa (ibid.). Lithologies of the upper Little Cedar Formation in central Iowa (Benton Co.) include lithographic-sublithographic limestones, pelleted intraclastic units, and barren to sparsely fossiliferous mudstones. To the north and west of this area a regional subareal exposure surface is interpreted to have developed during the offlap phase of Little Cedar deposition. In east-central and southeast Iowa, carbonate facies are increasingly open marine, characterized by skeletal wackestones with diverse marine biotas. In extreme east-central Iowa (Scott Co.), a submarine discontinuity surface developed at the end of Little Cedar deposition and separates open-marine units of the Little Cedar and Coralville formations. The onshore-offshore trend from north-central to southeastern Iowa is further suggested by thickness relationships of the Little Cedar Formation (Fig. 1). The thickest sediment accumulation and rates of carbonate production are interpreted to have coincided with areas of shallower water deposition. The zero edge of the Hinkle Member (Fig. 1) (regressive lithographic limestone at the top of the Little Cedar Formation) although eroded, indicates the approximate limit of southeastward progradation of restricted marine to nonmarine facies.

Detailed regional lithologic trends in the upper Little Cedar Formation were delineated through petrographic examination and description of closely-spaced thin-section samples from three cores along a transect perpendicular to suspected strand line (Fig. 1). Lithologic details are presented as a regional cross-section from Benton County to Scott County, Iowa (Fig. 2). Depositional environments are interpreted from the lithic framework, and establish a foundation for diagenetic investigations.

Detailed field studies in the Coralville Lake area have revealed a coarse-grained, cross-bedded echinoderm grainstone unit, the "Curtis Bridge" grainstone (Plocher, 1987; Bunker & Plocher, 1987) in the upper Rapid Member, of northern Johnson County, Iowa. Cross-bed dip direction data are plotted in a rose diagram (Fig. 1) and display a bimodal distribution perpendicular to interpreted strandline direction. The "Curtis Bridge" grainstone currently is the focus of a diagenetic study, and will be addressed further in the following discussions.

DEPOSITIONAL ENVIRONMENTS

For a lack of better descriptive terms, the depositional environments have been subdivided into inner shelf, inner shelf-margin, and middle shelf facies tracts. Use of these terms results from the failure of traditional terminology to adequately describe depositional trends and facies architecture of carbonate depositional systems in epeiric seas (see also comments by Bunker & Witzke, elsewhere in this guidebook).

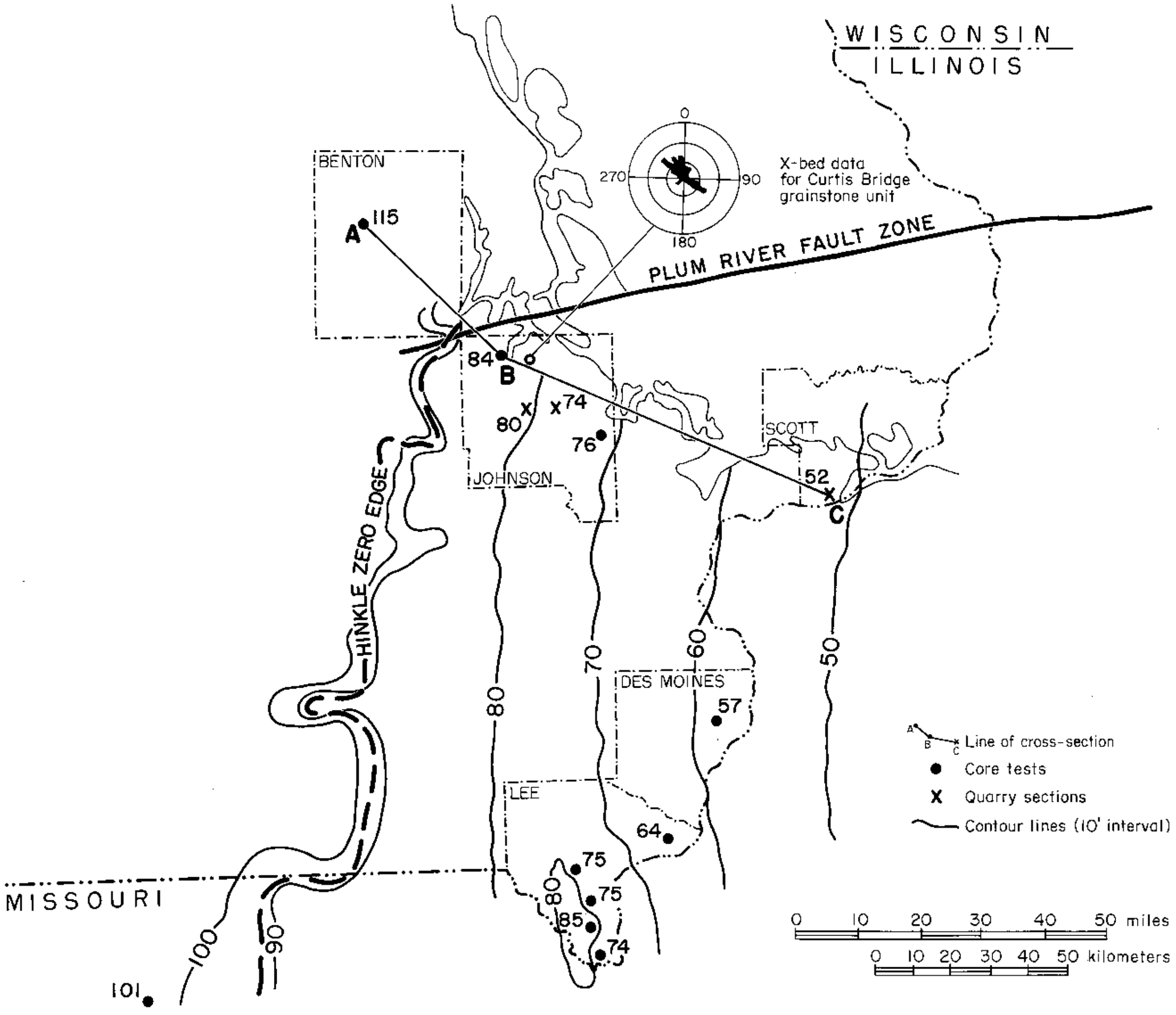

Figure 1. Isopach map of the Little Cedar Formation (unpublished map of Bunker, Iowa Geological Survey Bureau). Dip directions of cross bed data plotted on a rose diagram. Cross Bed data collected at Curtis Bridge Quarry, Johnson County, Iowa.

INNER AND MIDDLE SHELF ENVIRONMENTS

Inner Shelf

Nearshore Restricted Facies

Nearshore restricted facies include barren to sparsely fossiliferous mudstones and pelleted intraclastic grainstones. Skeletal grains become progressively more abundant in an offshore direction. Fine-grained abraded skeletal material includes: echinoderm, brachiopod and bryozoan debris. Some mudstone units are interlaminated with alternating pelleted intraclastic grainstones. This facies is interpreted to have been deposited in a nearshore position beyond effective wave reach. Circulation was physically restricted by an inner shelf-margin shoal complex. Fluctuating salinities may have posed biotic stresses, limiting biotic diversity and skeletal abundance in this facies. Nearshore restricted environments on the inner shelf were regionally expansive, extending for as much as a hundred kilometers shoreward beyond the inner shelf margin-shoal complex.

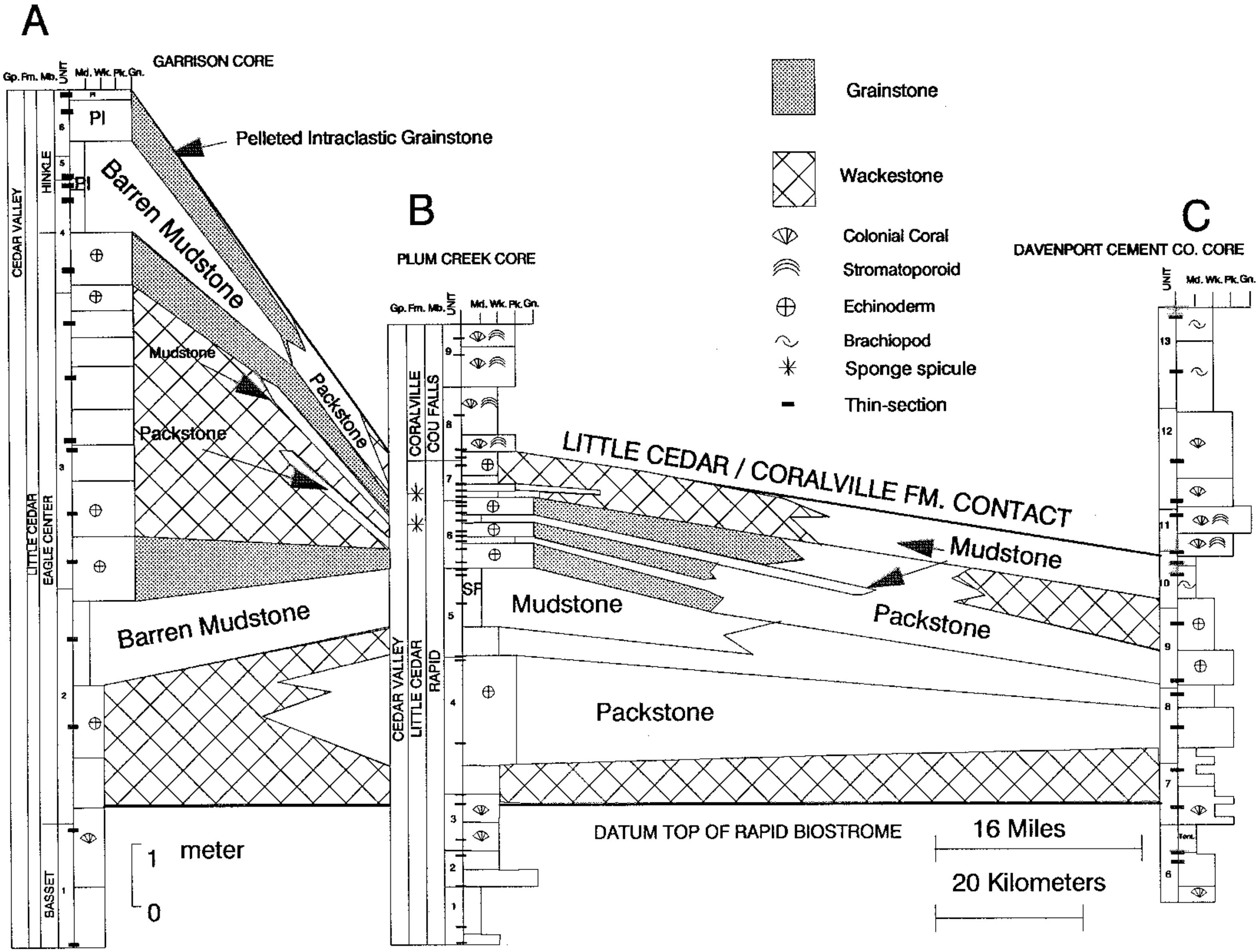

Figure 2. Regional lithic cross-section of the upper Little Cedar Formation, datum on the top of the biostromal unit. Skeletal grain symbols are used only for units dominated by a single skeletal grain type; other units are mixed skeletal.

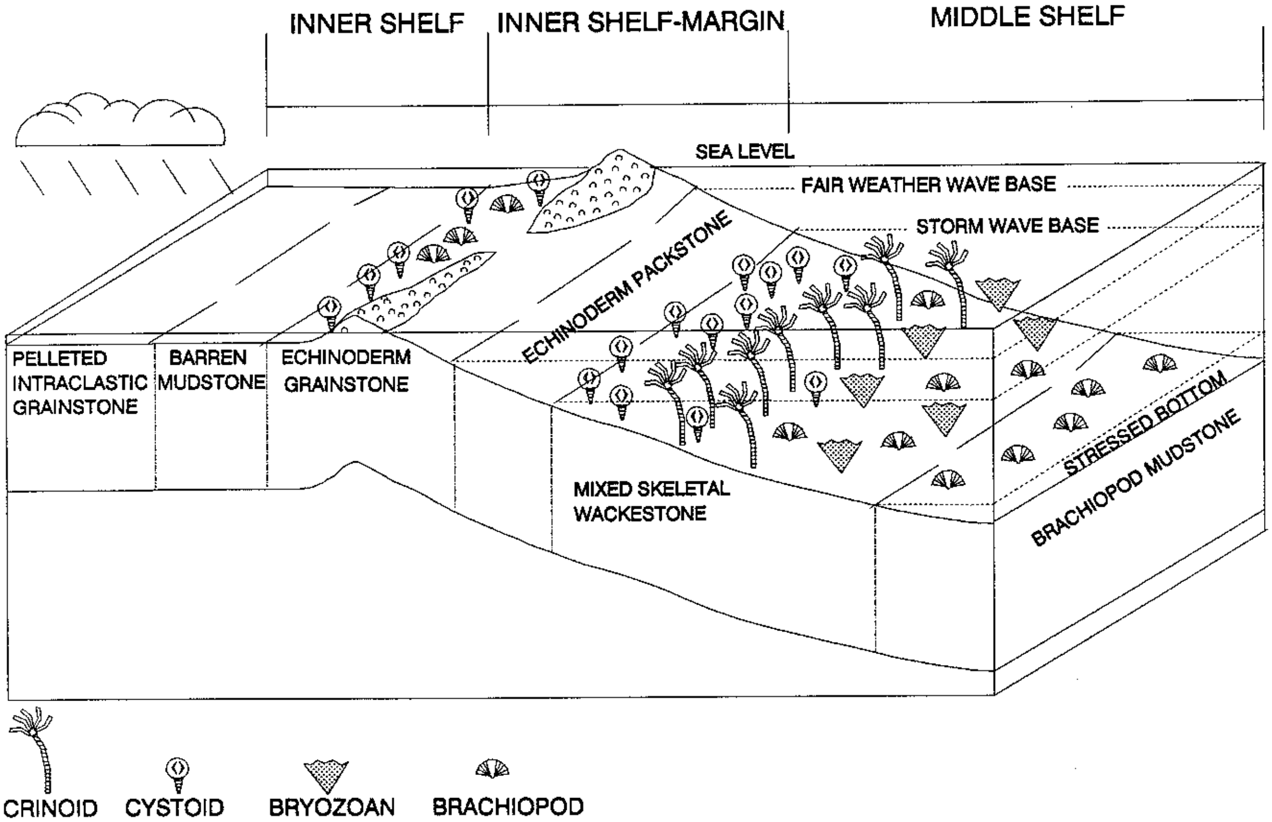

Figure 3. Depositional model for the upper Little Cedar Formation, with general biofacies relationships. Inner shelf facies tract - Benton County, inner shelf-margin facies - Johnson County, middle shelf facies - Scott County.

Inner Shelf-Margin

Shoal Complex Facies

Skeletal grainstone lithologies dominate the shoal complex. Echinoderm grainstones are prominent along the axis of the shoal, and grade offshore into mixed-skeletal grainstones. Skeletal grains include: echinoderm, brachiopod, bryozoan, tentaculite, ostracode and fish debris, and pachyporid corals. Syntaxial overgrowths on echinoderm grains are the dominant cement type. Echinoderm grainstones preserve an open framework of grains with few signs of subsequent compaction. Units along the main shoal axis display well developed high-angle cross-beds that become planar-bedded in distal shoal areas. Shoal facies are interpreted to have been deposited within effective fair weather wave base, resulting in the near total winnowing of carbonate muds. Shoal facies are limited regionally to a narrow belt a few kilometers wide trending parallel to the presumed strandline.

Near Shoal Facies

The near-shoal facies is composed of lime packstones. Echinoderm packstones occur near the shoal complex and grade offshore into mixed-skeletal packstones. Skeletal grains include: echinoderm, brachiopod, bryozoan, tentaculite, ostracode and fish debris, and pachyporid corals. The near-shoal facies is interpreted to have been deposited in a position below fair weather wave base, but evidence for periodic winnowing suggests a position within storm wave base. Portions of the near-shoal facies probably represent wash-over lobes of skeletal grains into a mud dominated environment. Near-shoal facies are more continuous regionally than the shoal facies, extending from distal shoal environments to as

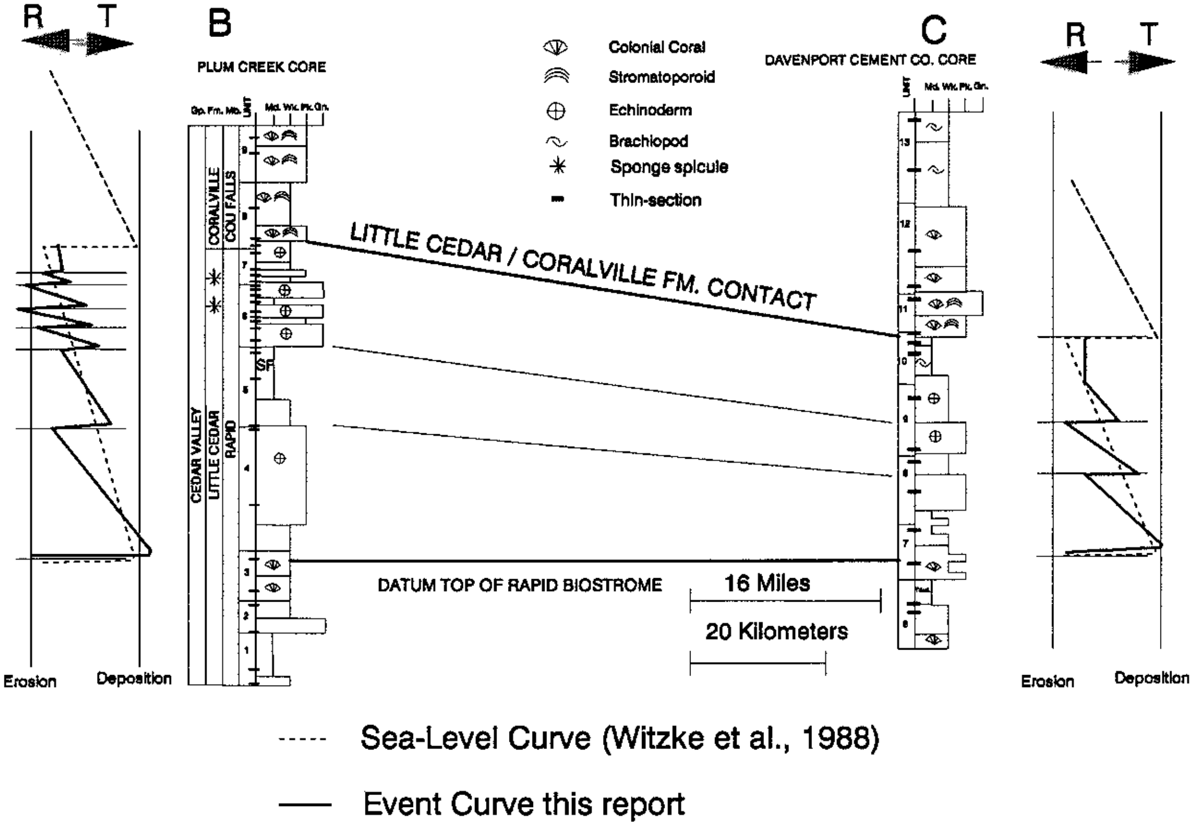

Figure 4. Event curve and eustatic sea level curve for the upper Little Cedar Formation. T and R, denote interpreted trangressive-regressive depositional trends.

much as 100 kilometers in the offshore direction.

Middle Shelf

Open-Marine Facies

Open-marine facies are represented by mixed-skeletal wackestones. Skeletal constituents include: echinoderm (articulated), brachiopod, bryozoan, tentaculite, ostracode and fish debris, and pachyporid corals. This facies is interpreted to represent deposition below effective storm wave base in a normal marine setting. In general the fauna is not dominated by any one skeletal element but rather all groups are subequally represented. Open-marine facies are regionally extensive in the offshore position beyond the near-shoal environments.

Restricted-Marine Facies

Restricted-marine facies are represented by sparsely fossiliferous lime mudstones. These mudstones are dominated by a single group of organisms, including; brachiopods, bryozoans, and sponges. These restricted-marine environments are interpreted to have been deposited below effective storm wave base in a position distal to open-marine facies. This environment is interpreted to have experienced benthic stress, as most contemporaneous macrofaunal elements are absent. Rare skeletal benthos are noted, presumably taxa tolerant of benthic stress. The probable cause of offshore benthic stress is interpreted to have resulted from conditions in a density-stratified seaway.

DEPOSITIONAL MODEL

Utilizing lithic and bio-facies data, a generalized depositional model has been constructed for the upper Little Cedar Formation (Fig. 3). Major facies tracts include; inner shelf,

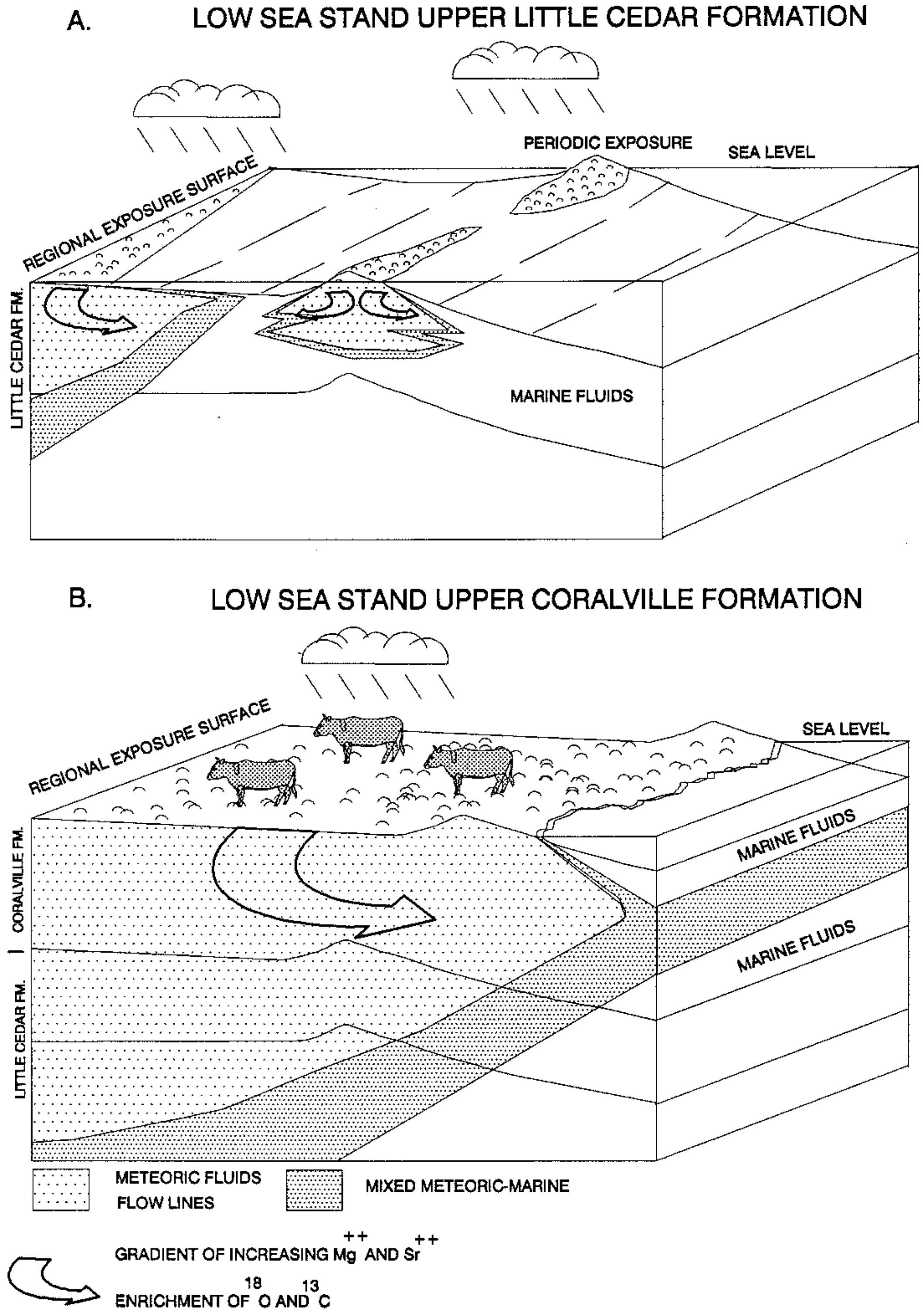

Figure 5. A) Diagenetic model for the meteoric event at the end of Little Cedar deposition. B) Diagenetic model for meteoric event at the end of Coralville deposition.

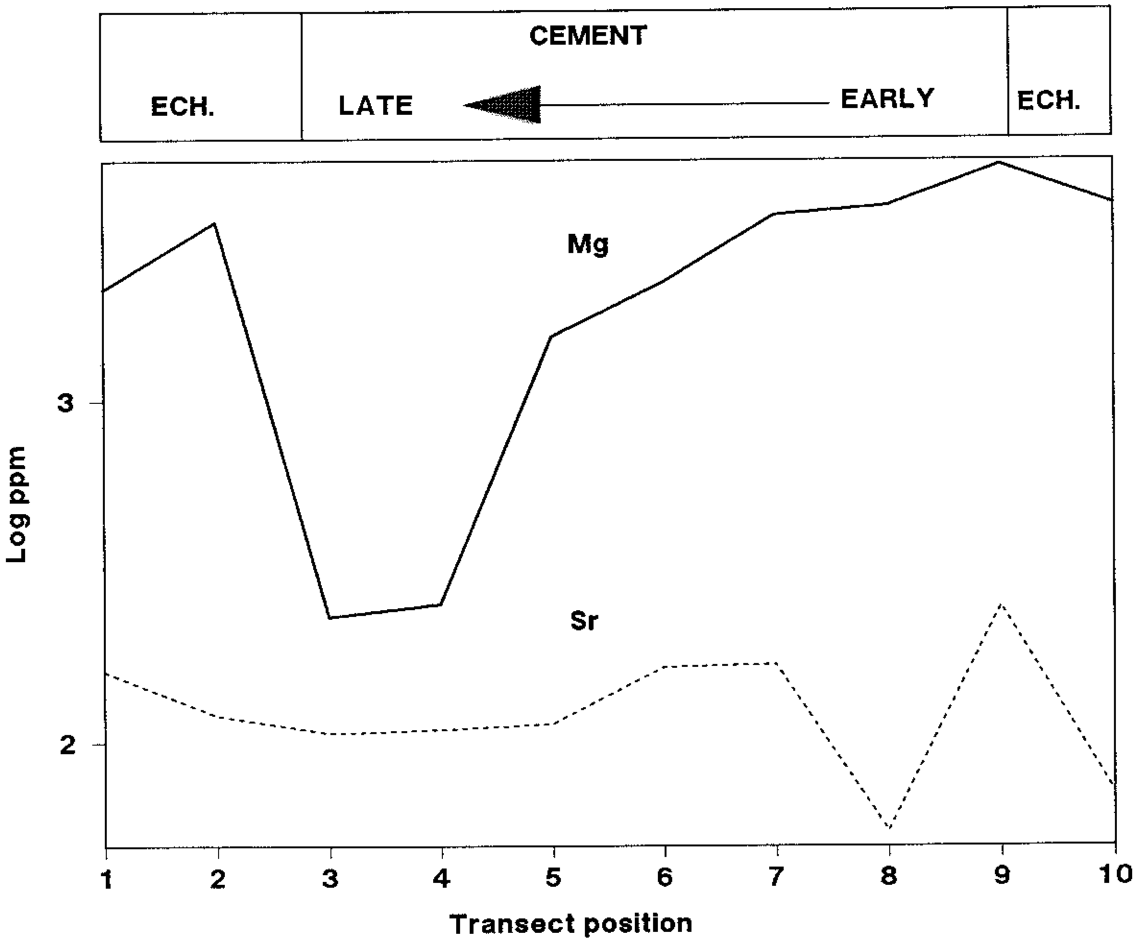

Figure 6. Electron microprobe trace-elemental transect through syntaxial overgrowth on echinoderm grains (ECH.) in the upper Rapid Member, Curtis Bridge Quarry, Johnson County Iowa. The cementation sequence was determined with cathodolumiscent petrography.

inner shelf-margin, and middle shelf. Biofacies trends are recognized in these environments. A cystoid community is interpreted to have flanked the inner shelf-margin in the inner shelf and middle shelf directions. In the inner shelf area a cystoid fauna and low-diversity brachiopod fauna are interpreted on the flank of the echinoderm shoal complex. In the middle shelf area the cystoids form an association with pachyporid (finger) corals and other open-marine components. Further offshore, the cystoid communities grade to crinoid dominance, that are further replaced seaward by bryozoan-brachiopod communities. In this model stressed bottom conditions, possible resulting from a density-stratified seaway, may exist with only a single species of brachiopod distal to the bryozoan-brachiopod community. This model implies that a relative sea-level rise would displace middle shelf environments up onto the inner shelf and inner shelf-margin areas. During periods of sea-level stillstands, continuous carbonate production would create an shallowing-upward depositional pattern. Successive episodes of sea-level rise are therefore interpreted to produce a series of shallowing-upward depositional sequences, each truncated by transgressive surfaces.

SEA LEVEL EUSTACY

Relative sea level changes are interpreted in the context of deepening and shallowing cyclic depositional sequences. Major transgressive-regressive lithic-sequences have been recognized in the Cedar Valley Group (Witzke et al., 1988), with formational status attributed to each major unconformity or discontinuity-bounded sequence. These are interpreted as responses to global eustatic changes in sea level (ibid.).

The Little Cedar Formation represents one of these eustatic cycles (Fig.4). The basal Solon Member, a stromatoporoid-coralline calcarenite, is interpreted as representing the initial transgressive portion of the cycle. There are striking lithic and biotic similarities between the Solon Member and the Cou Falls Member, the latter being the basal unit of the overlying Coralville Formation. The lower Rapid Member is interpreted to record deposition in the most offshore position within the cycle (ibid.). This is reflected by the widespread regional persistence of open-marine biofacies and lithofacies. The Rapid biostromes may represent a minor regressive lithic-unit that progradated in an offshore direction from the area northwest of Cedar Rapids, Iowa. As shallowing continued, the biostromes built-out beyond the inner shelf-margin area. In the middle shelf area the biostromes are thin and patchy in distribution. The units directly overlying the biostromes are interpreted to record a transgressive event. Deposition above this slight transgressive unit in the upper Rapid Member is interpreted to have occurred in progressively shallower water, culminating in a grainstone shoaling episode on the inner shelf-margin. Pelleted-intraclastic units and lithographic limestones (Hinkle Member), deposited in a restricted inner shelf area, progaded offshore during the upper Rapid shallowing phase to a position between Palo and Cedar Rapids, about 50 kilometers from the inner shelf-margin.

A regional interpretation of the upper Little Cedar Formation reveals a series of smaller-scale shallowing-upward sequences truncated by transgressive surfaces that are overprinted on the large scale overall regressive trend of the upper Little Cedar Formation. Small-scale shallowing-upward events are recognizable regionally and are interpreted to represent basin wide changes in depth relative to fair-weather wave base penetration. In the middle shelf area three such events are recognized (Fig. 4). In the inner shelf-margin area each of the small-scale events is comprised of several events of even lesser magnitude. Minor events are variable in short distances depending on proximity to the main shoal axis. Locations flanking the main shoal axis exhibit six or seven minor events while locations interpreted to be in the main shoal axis have only three cycles. In the main shoal axis, shoaling continued throughout with minor fluctuations, resulting in fewer recognizable cycles. Minor events are interpreted to represent either storms or small-scale intrabasinal changes in depth of wave base penetration.

DIAGENESIS IN THE UPPER LITTLE CEDAR FORMATION

Introduction

Diagenesis in the upper Little Cedar Formation is best addressed by two separate discussions. These are: 1) stabilization of metastable carbonates to calcite and dolomite and 2) the replacement of carbonates with different minerals. In general, the earliest diagenesis involves the alteration of aragonite (A) and high magnesium calcite (HMC), to low magnesium calcite (LMC). Common skeletal grains with original metastable mineralogies include echinoderm grains (HMC), and mollusc grains (A). Brachiopods, however, precipitate a LMC shell.

Stabilization of metastable carbonates can take place in several distinct diagenetic environments. These geochemical regimes may be distinguished by the chemical composition of the fluid within the sediments including; marine (sea water), meteoric (fresh water), and a zone of mixed meteoric-marine composition. Meteoric and marine environments are further subdivided into vadose and phreatic zones. In the vadose zone, sediment pores contain gases and liquids, while sediment pores in the phreatic regime are saturated with water.

During the regression at the top of the Little Cedar Formation, an echinoderm grainstone shoal complex developed on the inner shelf-margin. The "Curtis Bridge" grainstone

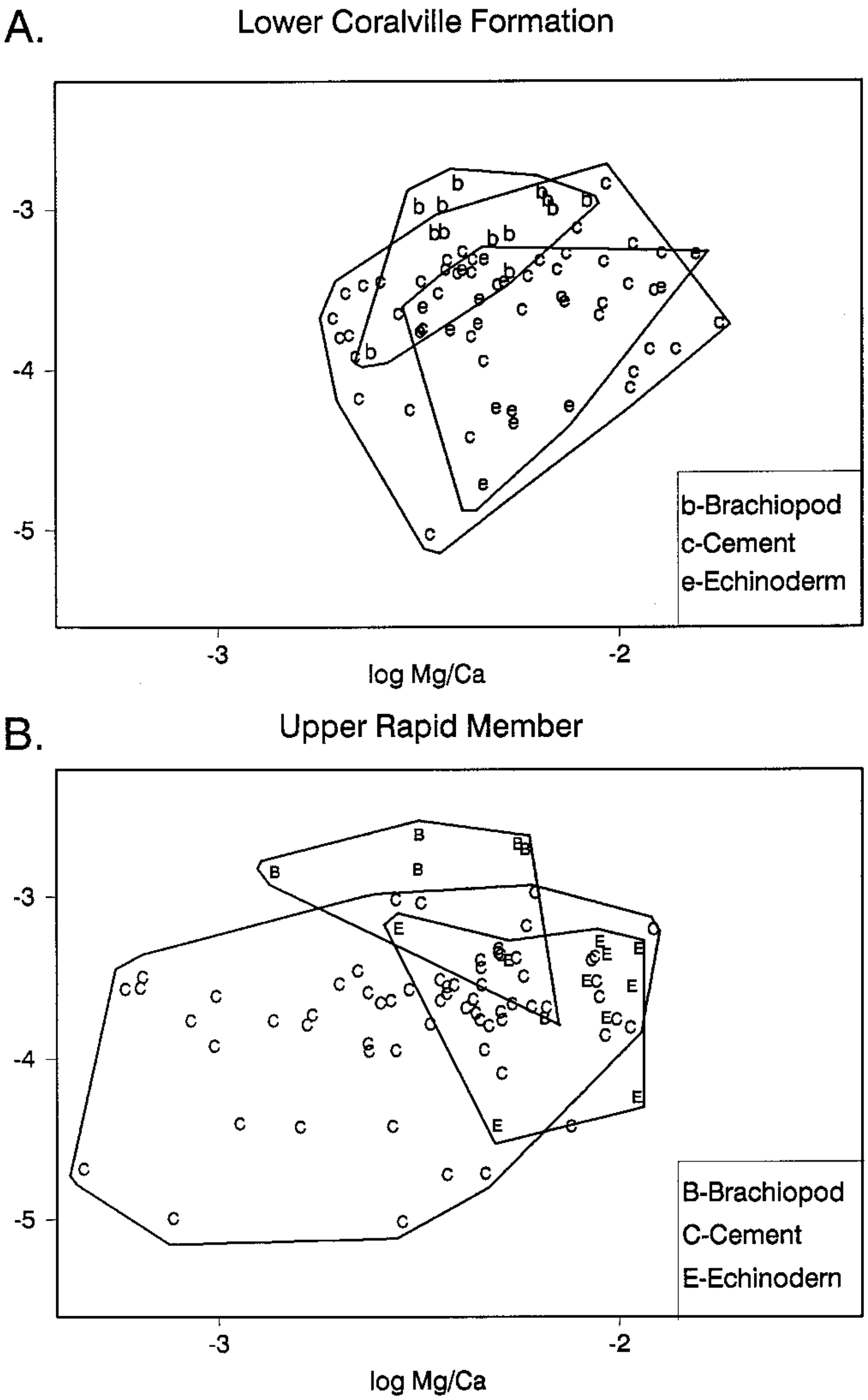

Figure 7. Bivariate plot of Sr and Mg concentrations in carbonate fabric constituents in the Lower Coralville and upper Little Cedar Formations. Samples from Curtis Bridge Quarry, Johnson County, Iowa.

(Plocher, 1987), is the focus of current diagenetic investigation due to the extensive development of pore-filling calcite spars that facilitate petrographic evaluation of the cementation history of the Little Cedar Formation.

During periods of relative sea-level lowstands (Fig. 5A), marine fluids are interpreted to have been progressively displaced by fluids of meteoric origin that were recharged from a regional subareal exposure surface north of Garrison in the inner shelf area. Meteoric influx is also interpreted to have locally taken place during the periodic subareal exposure of the grainstone shoals on the inner shelf-margin.

Carbonate petrography

Several techniques are utilized to interpret the diagenesis of the grainstones. Petrographically, the grainstone units on the main shoal axis form an open framework of echinoderm grains encased in syntaxial overgrowths that formed up to thirty percent of the rock volume. Prior to the emplacement of syntaxial cements this thirty percent volume represented intergranular porosity. Within the syntaxial overgrowths are inclusion-rich rims on echinoderm grains that may represent the relicts of an earlier metastable cement phase (Meyers & Lohmann, 1978; Plocher, 1987). There are also minor epitaxial cement rims on brachiopod grains.

In contrast to the upper Rapid Member, the basal unit of the overlying Coralville Formation is an abraded coralline-stromatoporoid packstone. Skeletal grains in this unit are overpacked with embayed and sutured grain contacts. This indicates that the lower Coralville Formation underwent substantial compaction. If the underlying grainstones were not cemented prior to the loading of the Coralville sediments, they would be expected to show similar evidence of compaction. Since this is not the case, it is interpreted that portions of the "Curtis Bridge" grainstone complex were at least partially cemented into a rigid framework prior to Coralville deposition and withstood subsequent compaction.

Carbonate geochemistry

Geochemical techniques are also commonly used in deciphering diagenetic histories. Skeletal grains of metastable composition are readily dissolved in fresh water. Upon dissolution, marine aragonite releases Sr^{++} ions into the fluid. Dissolving marine HMC grains release Mg^{++} ions into the solution. As dissolution of original carbonates proceeds, supersaturation of calcite is achieved, and Sr and Mg are precipitated as trace elements in LMC, but at a lesser concentration than in the fluid (Lohmann, 1988). Sr^{++} and Mg^{++} are depleted in fluids in areas proximal to meteoric recharge. Meteoric fluids are initially depleted of Mg^{++} and Sr^{++}, through progressive rock-water interactions there is a downflow enrichment of Sr^{++} and Mg^{++} ions in the fluid. Dissolution of metastable components is concurrent with, and in fact drives the precipitation of diagenetic LMC. Over time, there will be a decrease in the concentrations of Mg^{++} and Sr^{++} in the diagenetic fluid, due to exhaustion of metastable components available for dissolution. This decrease in Sr^{++} and Mg^{++} concentrations in the fluid will result in a temporal decrease in the concentrations of these elements incorporated in LMC cements (ibid.).

Temporal geochemical trends can be evaluated utilizing electron microprobe analysis of trace elements in zoned cements. Constructive crystal growth zonations are recognized in syntaxial overgrowths in the "Curtis Bridge grainstone" using cathodoluminescent (CL) microscopy. CL images were used to choose appropriate trace element transect locations and to evaluate the amount of alteration of skeletal grains (Brand and Veizer, 1980). The results of a trace element transect are plotted in (Fig. 6). The concentration of Mg^{++} in the cement decreases over time, apparently due to diminishing supplies of original HMC. The trend of Sr^{++} concentration is relatively suppressed, possibly because of a low abundance of aragonitic skeletons in the original sediment pile. Similar temporal trends are observed in cement transects in the overlying Coralville Formation, and are interpreted to have resulted from the meteoric stabilization event after Coralville deposition.

Trace element data can also be utilized to evaluate overall diagenetic regimes of sediment stabilization. In a meteoric flow system, there is a compositional gradient in the fluid, and resulting diagenetic rock phases, from the point of recharge, to the most distal margin of the fresh water lens. The compositional gradient can be

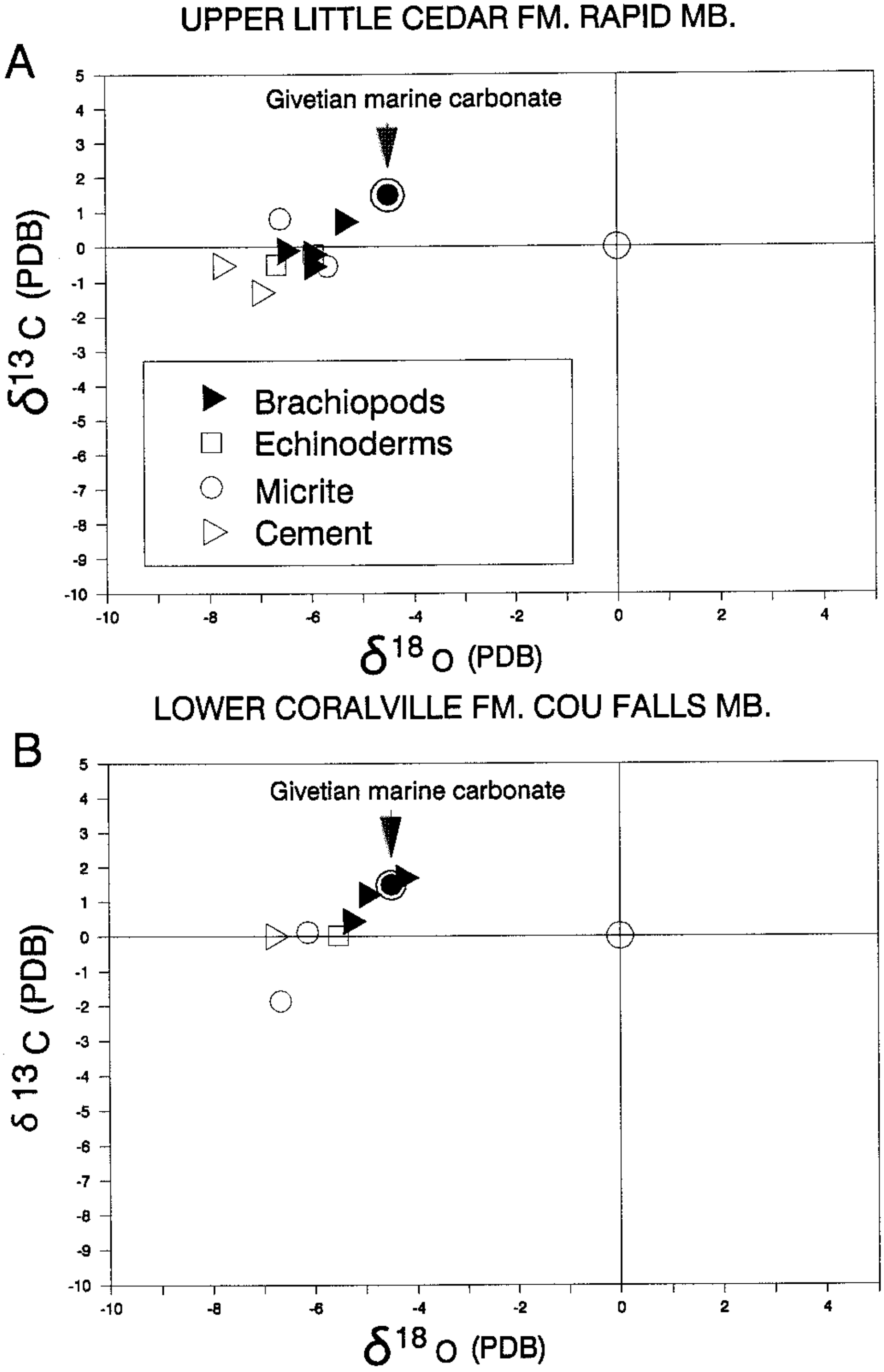

Figure 8. Bivariate plot of δ^{13}C and δ^{18}O data from carbonate fabric constituents in the upper little Cedar and Lower Coralville formations. Samples collected from Plum Creek Core, Johnson County, Iowa. Values for Givetian marine carbonate are from Lohmann (1988).

discussed by considering the end members of the system. At the point of recharge, the system is considered to be fluid-dominated (Lohmann, 1988). Fluid domination indicates that the fluid went through relatively few rock-water dissolution-precipitation reactions during the short residence time in contact with the sediments, thus the diagenetic products of these fluids are close in composition to that precipitated from fresh meteoric water. In the distal position, the fluids have gone through many rock-water dissolution-precipitation reactions, resulting in the composition of the diagenetic phases being closer to the bulk composition of the reacting sediment pile (ibid.). In considering a sediment pile composed of HMC, A, and LMC grains, it follows that diagenetic products formed in a rock-dominated system away from recharge will be enriched in Mg and Sr compared to the composition of products formed in a proximal fluid-dominated system (Fig. 5A, B; Brand and Veizer, 1980). The same relationship is true for the stable isotopes of oxygen and carbon. Products formed in a distal meteoric position will have an isotopic signature closer to original marine carbonate values because the fluid composition is controlled by the dissolution of carbonate constituents that were originally precipitated in marine environments. Products formed in a proximal meteoric position will have isotopic compositions closer to that of calcite precipitated from freshly-recharged meteoric water, because comparatively few rock-water dissolution reactions have taken place. Calcites precipitated from meteoric waters have more depleted $\delta^{18}O$ values than contemporaneous marine carbonates, as meteoric waters are isotopically depleted because of fractionation resulting from evaporation/condensation. Meteoric calcites are characterized by invariant $\delta^{18}O$ values, with relatively variable $\delta^{13}C$ values resulting from variable mixtures of isotopically light soil-derived carbonate and heavier marine carbonate. This trend yields a characteristic "meteoric calcite line" that is formed in proximal settings, while the composition of more distal meteoric calcites approach the composition of the original marine carbonates. These two trends combine to form an "inverted-J trend" that is characteristic of limestone stabilization in meteoric environments (Lohmann, 1988).

It has been demonstrated that different carbonate fabric constituents stabilize at different rates and times, thus acquiring different trace element and isotopic values (Popp et al., 1986). Consequently it is important to evaluate the trace element and isotopic chemistry of individual fabric constituents. LMC brachiopod shells are less susceptible to diagenetic alteration. It has been demonstrated that brachiopods approximately record the chemistry of calcite precipitated in a marine fluid (Popp et al., 1986a). In contrast, syntaxial cements have a chemistry that records precipitation in fresh water that is variable depending on position in the meteoric flow system. The trace elemental and stable isotopic trends of the Upper Rapid Member and of the Lower Coralville Formation are compared to evaluate the relationship between the diagenesis in the upper Rapid grainstone ("Curtis Bridge) and the lowermost Coralville Formation (Cou Falls Member) These data have been analyzed to evaluate two alternative scenarios for cementation of the "Curtis Bridge" grainstone. Cementation could have taken place during the sea-level lowstand and associated meteoric event at the end of upper Little Cedar deposition (Fig. 5A) or at the sea-level lowstand and meteoric event at the end of Coralville deposition (Fig. 5B).

If cementation in the "Curtis Bridge" grainstones took place during early subareal exposure, a proximal setting would be required, and syntaxial cements in the upper units of the grainstone would be expected to be depleted in Sr and Mg relative to brachiopod calcites, and have depleted isotopic values characteristic of diagenetic calcites precipitated from meteoric waters.

If cementation of the grainstone took place during the sea-level lowstand ending Coralville deposition, the close vertical proximity of the geochemical samples (less than 1 meter apart) would require that both samples stabilized in a distal meteoric setting, where the trace elemental composition of the syntaxial cements would be relatively enriched in Sr and Mg, showing values similar to brachiopod data and isotopic values close to Givetian marine carbonate (as defined by Lohmann, 1988). Comparison of the trace elemental composition of grains and cements in the upper Little Cedar Formation and lower Coralville Formation (Fig. 7) reveal that some of the cements in the upper Little Cedar Formation are depleted with respect to Sr and Mg relative to

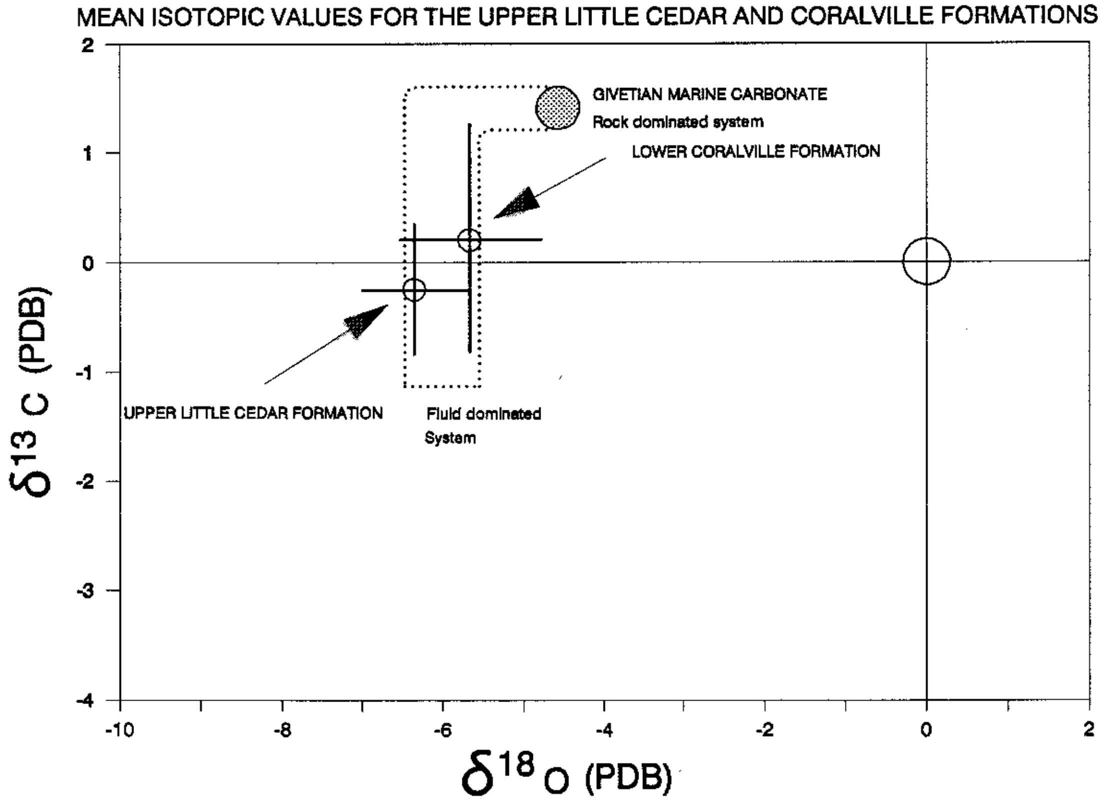

Figure 9. Bivariate plot of mean carbon and oxygen isotopic values for data from upper Little Cedar and lower Coralville Formations, Plum Creek Core Johnson County, Iowa. Bars show magnitude of standard deviations from the mean. Values for Givetian marine carbonate from (Lohmann, 1988).

brachiopod calcites. Cements in the lower Coralville Formation, however, have similar ranges of Mg and Sr contents to those of brachiopod calcites. Comparisons between the two data sets illustrate similar brachiopod chemistries in the two units, but marked dissimilarities in the ranges of calcite cement compositions. Dissimilarities in cement composition between the units are interpreted to have resulted from precipitation in different positions during two different meteoric phreatic events. It is interpreted that the "Curtis Bridge" grainstones of the upper Little Cedar Formation were at least partially cemented during early meteoric diagenesis on the inner shelf-margin during the low sea-level stand at the end of Little Cedar deposition, predominantly in a proximal water-dominated system (Fig. 5A). Conversely, the lower Coralville Formation is interpreted to have initially stabilized in a rock-dominated system in a more distal meteoric position during the lowstand ending deposition of the Coralville Formation (Fig. 5B).

Stable isotopic data supports these interpretations. Carbonate fabrics in the lower Coralville Formation (Fig. 8) more closely approach suggested Givetian marine carbonate values (Lohmann, 1988). Rock constituents analyzed from the "Curtis Bridge" grainstones, however, are more depleted with respect to carbon and oxygen isotopic values expected from marine carbonates (Fig. 9), and are interpreted to have stabilized in a proximal meteoric setting.

Silica replacement

Carbonate replacement by silica occurs mainly to the northwest, in an area interpreted as the inner shelf setting. In the inner shelf area, a three meter interval in the upper Eagle Center Member was completely replaced by bedded chert. The original lithologies of this interval are inferred to be fine-grained echinoderm and mixed-skeletal grainstones, packstones, wackestones and mudstones. The degree of silicification decreases southeastward toward the inner shelf-margin. In the inner shelf-margin area, silicification occurs in packstone and grainstone units within the same interval in the upper Rapid Member. Chert in this area ranges from nodular-bedded to nodular. Silicification in packstone and grainstone lithologies suggests a possible porosity control. These lithologies are interpreted to have served as porosity conduits for diagenetic fluids making them more susceptible to alteration than the less porous units that confine them. Silicification also can be observed at a microscopic scale. Skeletal grains throughout the upper Little Cedar Formation, in both shelf and shelf-margin settings, are partially to completely replaced with silica.

Skeletal grains that most commonly seem to be replaced, include corals (outermost rind), brachiopods, and echinoderm grains. Replacement at this scale may also be related to porosity and organic content in the microstructure of these skeletal grains (Knoll, 1985). No silicification is noted in positions interpreted to be middle shelf.

Dolomite replacement

Replacement of calcite by dolomite follows a similar regional trend as silicification. Dolomitization is volumetrically greatest in the interpreted inner shelf area. In the inner shelf setting nearly all of the Eagle Center Member is replaced with dolomite. To the south in the inner shelf-margin and middle shelf areas, dolomite occurs as scattered rhombs replacing matrix and portions of individual skeletal grains in the upper Rapid Member.

Glauconite replacement

Glauconite occurs in the upper Little Cedar Formation as a partial to complete replacement of skeletal grains and intraclasts. Echinoderm grains are the most common grain to be replaced followed by bryozoans. Regionally, glauconite accumulation along the outcrop belt is restricted to Johnson County within the grainstone facies on the interpreted inner shelf-margin.

Paragenesis

Petrographic and field observations permit general statements regarding chronologic relationships of mineral replacements. Complications in interpreting relative timing of replacements arise from multiple episodes of alteration to a single mineral species. Replacement of skeletal grains by glauconite is considered to be relatively early, prior to the lithification of sediment. Chert nodules in the inner shelf setting preserve original depositional fabrics, whereas dolomite encasing the nodules cross-cut and obliterate depositional fabrics. In this diagenetic setting, silicification is therefore interpreted to have formed prior to dolomitization. Chert nodules in the inner shelf-margin setting are encased in a packstone matrix that was deformed by compaction around the nodules. This fabric relationship indicates silicification prior to complete lithification of the sediment. In the inner shelf-margin setting, chronologic relationships between dolomite and silicification are yet to be resolved.

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REVISED TAXONOMY AND BIOSTRATIGRAPHY OF TRILOBITES FROM THE CEDAR VALLEY GROUP OF EASTERN IOWA, WESTERN ILLINOIS

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INTRODUCTION

Study of Cedar Valley trilobites has been at a virtual standstill for some time. James Hall in his great monograph on Devonian trilobites (1888) described three new species: *Proetus occidens*, *Proetus prouti* and *Dalmanites barrisi* from the "Hamilton" Formation of Eastern Iowa. Otto Theodore Walter in a 1923 report published by the Iowa Geological Survey described seven new species: *Proetus searighti*, *Proetus bumastoides*, *Proetus arietinus*, *Proetus nortoni*, *Goldius thomasi*, *Cyphaspis raripustulosus* and *Asteropyge fitzpatricki*. He also reprinted Hall's descriptions of *Proetus clarus*, *Proetus rowi*, *Proetus crassimarginatus*, *Proetus prouti*, *Proetus occidens*, *Dalmanites barrisi* and *Phacops rana*. Niles Eldredge (1972) published a paper on *Phacops rana* and *Phacops iowensis*.

In the sixty five years since Walter's study many complete specimens of species that were originally described from only fragmentary remains have been recovered. Additionally, many of the new collections record precise stratigraphic occurence data. The purpose of this paper is to update the taxonomy of Cedar Valley trilobites and to propose trilobite assemblage zones that are of value for local correlation.

STUDY MATERIAL

Studied specimens are from five collections: Fryxell Geology Museum, Augustana College, Rock Island, Illinois; Putnam Museum, Davenport, Iowa; Paleontological Repository at the University of Iowa, the private collection of Mr. Marv Hogue, Cedar Rapids, Iowa and a collection of over two hundred trilobites assembled over a five year period by the author. Seventeen different species are recognized, and of these at least three appear to be either new species or are established species that have not been recorded previously from the Cedar Valley Group. The following species have been noted:

Phacops rana (Green)
Phacops iowensis (Delo)
Greenops (Neometacanthus) barrisi (Hall)
Greenops (Neometacanthus) fitzpatricki (Walter)
Greenops (Greenops?) sp.
Dechenella (Basidechenella) prouti (Hall)
Dechenella (Basidechenella) rowi (Green)
Dechenella (Basidechenella) cf. *D. clarus* (Hall)
Dechenella (Basidechenella) cf. *D. rowi* (Green)
Dechenella (Dechenella) nortoni (Walter)
Dechenella (Dechenella) haldemani (Hall)
Crassiproetus occidens (Hall)
Crassiproetus arietinus (?) (Walter)
Crassiproetus searighti (Walter)
Crassiproetus bumastoides (Walter)
Cyphaspis (?) *raripustulosus* (Walter)
Scutellum thomasi (?) (Walter)

TRILOBITE LOCALITIES

Trilobites collected as part of this study are from Little Cedar Formation localities in and around the Quad-Cities area of eastern Iowa and western Illinois. The majority of the specimens are from: Collinson Brothers Quarry, Milan, Illinois; Allied Quarry, Rock Island, Illinois; Davenport Cement Company, Buffalo, Iowa; as well as sections exposed along stream cuts in the area and the rip-rap along the Mississippi River on the Illinois side. Additional specimens were found at the Lake Macbride Spillway section, outcrops along Coralville Lake, the rip-rap along Highway 218 near Curtis Bridge, and River Products Company Conklin Quarry, all in Johnson County, Iowa. Exact stratagraphic

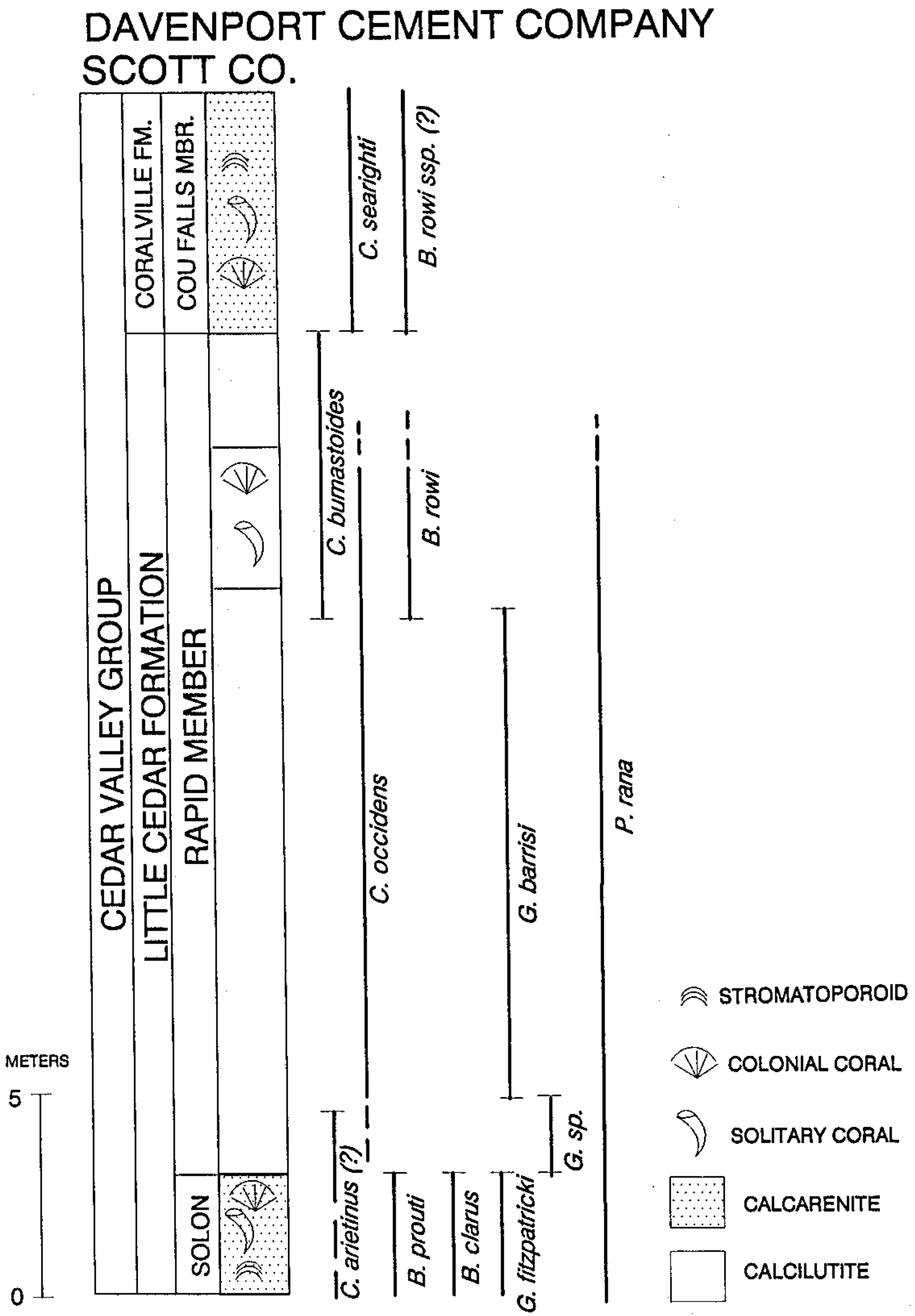

Figure 1. Stratigraphic ranges of Cedar Valley trilobites in the Quad-Cities area, east-central Iowa and western Illinois.

position was noted on specimens found in-situ; specimens found in "float" or in the rip-rap can usually be assigned to a limited stratigraphic interval of the Cedar Valley based upon distinctive matrix lithology.

TRILOBITE ASSEMBLAGES

Study of the stratigraphic range of the trilobites collected in the Quad-Cities area reveals five distinctive trilobite assemblages that appear to be related to lithofacies. The five assemblages include in ascending order: Upper Solon (*"Profunda"*), Lower Rapid, Middle Rapid, Upper Rapid and Lower Coralville (Fig. 1). No attempt was made to study trilobites from the lower Solon because of scarcity of material and poor stratagraphic information on the few specimens that are available. Also the lower Solon is not present in the study area. However, trilobites restricted to the lower Solon includes: *Phacops iowensis*, *Dechenella nortoni*, *Dechenella haldemani*, and *Scutellum thomasi* (?). *Cyphaspis raripustulosus* was not included in this study because the only specimen known is the holotype (SUI 9113) which was collected at Mid River Marina Quarry (Stop 4).

Upper Solon

The skeletal calcarenites of the upper Solon (*"Profunda"* zone) contain an abundant and varied macrofauna (Witzke et al., 1985). Trilobites are rare but generally complete. The trilobites generally occur in specifically segregated groupings of two or three specimens; this situation has also been noted by trilobite workers in the Devonian of New York (Speyer, 1985). Trilobites occurring in this interval include: *Phacops rana spp.*, *Crassiproetus arietinus* (?), *Basidechenella prouti*, *Neometacanthus fitzpatricki* (?), and *Basidechenella* cf. *B. clarus*. The largest specimens of Cedar Valley trilobites occur in this zone. This same interval along Coralville Lake and Lake Macbride Spillway has yielded excellent specimens of *B. prouti*, *B. cf. B. clarus* and *P. rana ssp.*. A slab containing three complete specimens of B. prouti was collected in-situ at the outcrop just south of the Lake Macbride Spillway directly above the stromatoporoid biostrome.

Lower Rapid Zone

This interval contains the most abundant and best preserved trilobite fauna. Species present include *Phacops rana norwoodensis*, *Crassiproetus arietinus* (?) and *Greenops* sp.. The majority of trilobites collected from this interval were found in nonsegregated clusters in large burrows at the base of Bed 13 (Witzke,et al.,1985). Only rarely are trilobites found outside of the burrows, these being found in the shaly limestone that surrounds the burrows. On weathered slabs these burrows extend for two feet or more with some being up to five inches wide and standing out an inch or more in relief. The trilobites appear to have been swept into these burrows by currents or possibly storms, as invariably they are located at the end of a long burrow in a jumbled mess in various stages of disarticulation. One burrow collected contains a complete *P. rana norwoodensis*, three complete *C. arietinus* (?), twenty three *Greenops* sp. in various stages of disarticulation, and an articulated blastoid, *Nucleocrinus melonformis* (?). Mr. Marv Houge has a large collection of trilobites from the Cedar Rapids area from the lower Rapid. His collection includes *P. rana norwoodensis*, *C. arietinus* (?) and *Greenops* sp.. It is interesting to note that none of his specimens were collected from burrows.

Middle Rapid

The middle Rapid is dominated by fossiliferous calcilutites separated by thin shaly partings (Witzke et al., 1985). This interval lies within the *"bellula"* zone of Stainbrook. The trilobite fauna of this zone includes *Phacops rana norwoodensis,* Crassiproetus occidens *and Greenops (Neometacanthus) barrisi*. The majority of specimens are molted exoskeletons, isolated cephalons, pygidia and only rarely complete specimens. The last occurrence of *N. barrisi* in Bed 18 (Witzke,etal., 1985) marks the extinction of the Superfamily Dalmanitacea in Iowa. *N. barrisi* is abundant on some bedding planes in this zone, and slabs containing assemblages in various stages of disarticulation are known from the Vinton, Moscow and Atalissa quarries in eastern Iowa.

Upper Rapid

This zone correllates with the *"Pentamerella"* and *"waterlooensis"* zones of Stainbrook (Beds 19-24 of Witzke et al., 1985). This interval is dominated in the Quad-Cities area by crinoidal wackestones with some packstone lenses. Trilobites occurring in this zone include: *Phacops rana norwoodensis*, *Crassiproetus occidens*, *Crassiproetus bumastoides* and *Dechenella (Basidechenella) rowi*. In all of the previous assemblages *P. rana* was by far the most abundant trilobite, but in this assemblage the proetids clearly dominate. It is possible that the last occurrence of *P. rana* in the middle part of this zone marks the extinction of the Order Phacopida in Iowa. *C. occidens* and *B. rowi* do not range completely through this zones. Many hours of collecting in the upper *"waterlooenesis"* zone yielded only rare pygidia and a free cheek of *C. bumastoides*. Trilobites are very rare in this zone in the Coralville Lake area; perhaps they preferred the more offshore environments to the east of the Iowa City area (See Plocher,herein).

Lower Coralville

Calcarenitic limestones of the lower Coralville Formation are not well exposed in the Quad-Cities area. However this interval at Buffalo, Iowa has produced a few specimens. Trilobites noted include isolated cephalons and pygidia of *Crassiproetus searighti* and *Dechenella (B asidechenella) rowi* spp. (?). In all of the collections studied for this paper only one complete specimen from this interval was noted. A complete, though poorly preserved specimen of *B. rowi* spp. (?) is in the collection of the Putnam Museum. In the Iowa City area where the Coralville Formation is better exposed fragments of these two species are common in the lower beds.

SYSTEMATIC DESCRIPTIONS

Phylum Arthropoda
Class Trilobita
Order Ptychopariida
Suborder Illaenina
Superfamily Proetacea
Family Proetidae
Subfamily Proetinae

Crassiproetus(Stumm, 1953)

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 (Reprinted from Stumm, 1953).

Crassiproetus occidens (Hall,1861) (Fig. 2, no. 9)

Diagnostic Features: Differs from *C. searighti* and *C. arietinus* in lack of glabellar furrows, differs from *C. bumastoides* in possesson of occipital lobes. Pygidium differs from all other Cedar Valley *Crassiproetus* in possessing an axis that tapers to an obtuse apex.

Occurrence: Middle and Upper Rapid.

Remarks: Widespread geographical distribution in eastern Iowa and western Illinois. Hall's description based on pygidia collected at Buffalo, Iowa. Complete specimens now allow rediscription.

Crassiproetus bumastoides (Walter,1923) (Fig. 2, no. 10)

Diagnostc Features: This distinctive species of *Crassiproetus* differs from all others in the Cedar Valley by lacking occipital lobes. It is also characterized by a convex cephalon which lacks glabellar furrows, and has very small eyes. The lateral and anterior border of the cephalon is striated. Pygidium is smooth with annulations nearly obsolete.

Occurrence: Upper Rapid.

Remarks: This species is similar and perhaps even conspecific with *Crassiproetus alpenensis* of the Traverse Group of Michigan. These appear to be the only two species of *Crassiproetus* that lack occipital lobes.

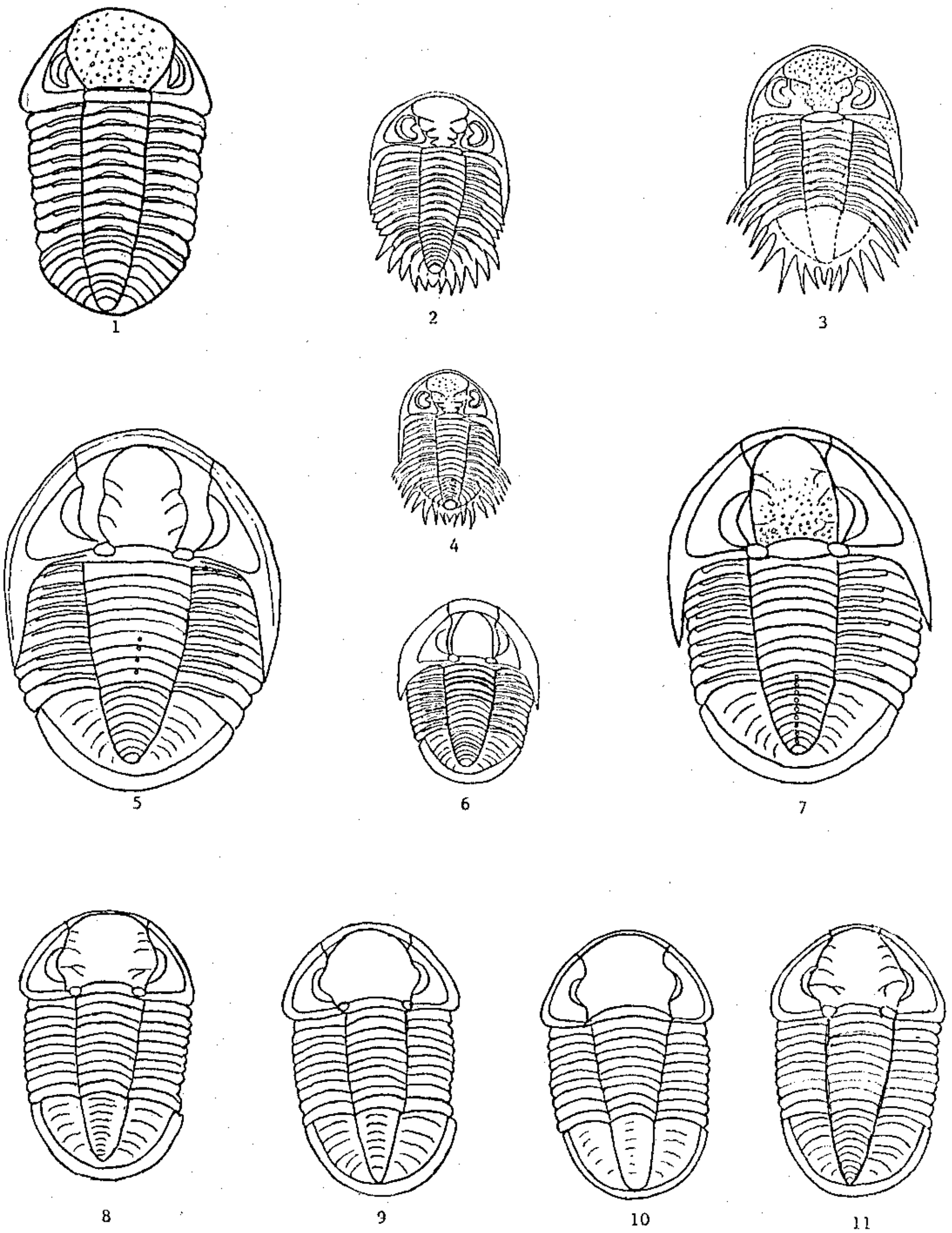

Figure 2. Cedar Valley trilobites from the Quad-Cities area. 1. *Phacops rana*, 2. *Greenops* sp., 3. *Greenops fitzpatricki*, 4. *Greenops barrisi*, 5. *Basidechenella prouti*, 6. *Basidechenella rowi*, 7. *Basidechenella* cf. *B. clarus*, 8. *Crassiproetus arietinus*, 9. *Crassiproetus occidens*, 10. *Crassiproetus bumastoides*, 11. *Crassiproetus searighti*. *(X1)*

Crassiprotus searighti (Walter,1923) (Fig. 2, no. 11)

Diagnostic Features: Cephalon of *C. searighti* is almost identical to that of *C. arietinus* (?), but has a higher vaulted free cheek and smaller eyes. The pygidium of *C. searighti* is very different from *C. arietinus* (?), the axis of *C. arietinus* (?) is much broader and the annulations and pleural ribs are much less defined than *C. searighti*.

Occurrence: Coralville Formation.

Remarks: It is possible because of the great similarity between *C. searighti* and *C. arietinus* that they are part of an evolutionary sequence. *C. searighti* is common in the calcarenitic coralline beds of the lower Coralville, whereas *C. arietinus* is found in the calcarenitic coralline beds of the upper Solon and the lowest beds of the Rapid where corals are still common.

Crassiproetus arietinus (?) (Walter,1923) (Fig. 2, no. 8)

Diagnostic features: Cephalon with narrow border, large eyes and glabellar furrows represented by faint color markings. Pygidium with broad axis extending nearly to the border. Annulations and pleural ribs indistinct.

Occurrence: Upper Solon-Lower Rapid

Remarks: Specimens from this interval have been assigned doubtfully to *C. arietinus*. The holotype (SUI 9122) is a fragmentary but complete specimen in which the glabella and the pygiidium have been exfoliated. Since these two features are critical in identifying different species of *Crassiproetus*, it will be impossible to assign any material to this species with certainty. The holotype agrees with the specimens collected in being highly convex, possessing occipital lobes and having a broad axis. The stratigraphic information with the holotype is poor, it was found "in the Cedar Valley Formation in Johnson County". It is possible that *C. arietinus* (?) represents a new species.

Subfamily Dechenellinae

Dechenella (Basidechenella) (Richter,1912)

Glabella tapering rather gradually, lateral furrows faint; occipital lobes not separated; genal platforms plane. Pygidium moderately elongate; axis with 12 or 13 rings; pleural fields with about 8 ribs(Moore,1959).

Dechenella (Basidechenella) prouti (Shumard,1863) (Fig. 2, no. 5)

Diagnostic features: Differs from all other Cedar Valley Dechenellinae in having a genal spine that extends to the seventh thoracic segment and having a wide, deeply sulcate frontal border. Three pairs of glabellar furrows are represented by faint color lines.

Occurrence: Upper Solon.

Remarks: One of the specimens (PL15, Figs. 6,7) figured by Wlater in his paper as *B. prouti* is actually *B.* cf. *B. clarus*. Four different species of *Basidechenella* in the Repository at the University of Iowa have been identified as *B. prouti*. This is disturbing because James Hall redescribed and illustrated *B. prouti* in his monograph. The length of the genal spine is enough to separate it from any other species of *Basidechenella* from the Cedar Valley.

Dechenella (Basidechenella) rowi (Green,1838) (Fig. 2, no. 6)

Diagnostic Features: Differs from other Cedar Valley *Basidechenella* by lacking glabellar furrows and by possessing a genal spine that reaches the third thorasic segment.

Occurrence: Upper Rapid.

Remarks: This species has a wide geographic range, also being known from the Traverse Group of Michigan,and the Hamilton Group of New York and Pennsylvania. In the Little Cedar Formation it is most common in the crinoidal wackestones of the upper Rapid. Fragments of a very closely related species or subspecies are known from the lower Coralville Formation, Cou Falls Member from both the Quad-Cities and Iowa City areas. The Coralville subspecies(?) differs from the Rapid species in having a higher vaulted cheek with a narrower genal spine and faint glabellar furrows that appear as color markings.

Dechenella (Basidechenella) cf. *B. clarus* (?) (Hall,1861) (Fig. 2, no.7)

Diagnostic Features: Genal spine extends to the third thoracic segment, glabellar furrows conspicuous, glabella covered with pustules that become coarser posteriorly. Pygidium possesses nine prominent axial nodes.

Occurrence: Upper Solon.

Remarks: This species was referred to by Norton (Iowa Geological Survey, Ann. Rpt., v.

9, p. 450) and Walter (1923) as *B. clarus*. However, the genal spines in B. clarus reach the fourth thoracic segment, glabellar furrows are, obsolete and the glabella lacks pustules. Additionally, Hall made no mention of axial nodes. The type specimen of *B. clarus* is from the Corniferous limestone of New York which is significantly older than the Cedar Valley Group. This species most closely resembles *B. nodosa* (Stumm) from the Traverse Group of Michigan, but differs in having a much shorter genal spine.

Order Phacopida
Suborder Phacopina
Superfamily Dalmanitacea
Family Dalmanitidae
Subfamily Asteropyginae

Greenops (Neometacanthus) (Richter and Richter,1948)

Cephalon with palpebral lobes high above posterior part of glabella, adjacent region of fixigenae sloping steeply toward axial furrows. Thoracic pleural processes are long, spikelike. 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) barrisi (Hall,1888) (Fig. 2, no. 4)

Diagnostic Features: Pygidium with spikelike processes, triangular shaped terminal spine, long spikelike thoracic spines, and cephalon covered with minute tubercles. Thoracic axis and pleurae bear a median row of tubercles.

Occurrence: Middle Rapid.

Remarks: Small species, an average adult specimen being 15 millimeters long. The best evidence for these specimens representing adults and not juveniles is that they occur with normal sized *P. rana* and *C. occidens*. *G. barrisi* is possibly conspecific with *G. alpenensis* (Stumm) of the Traverse Group. Stumm admits in his description that "*G. alpenensis* resembles *G. barrisi* from the Cedar Valley Limestone of Iowa, but that species is known only from pygidia".

Greenops (Neometacanthus) fitzpatricki (Walter,1923) (Fig. 2, no. 3)

Diagnostic Features: Differs from *N. barrisi* by not having the axis and pleurae of the pygidium subdivided, terminal spine is slender with nearly uniform width throughout its length.

Occurrence: Upper Solon, lower Solon (?).

Remarks: A slab containing four specimens of this species in various stages of articulation was collected from the rip-rap along the Mississippi River at Rock Island, Illinois. The axis of the pygidium is incompletely preserved but these specimens agree with the holotype (SUI 9080) and a nearly complete specimen (SUI 9081) in University of Iowa Repository.

Greenops (Greenops ?) sp. (Fig. 2, no. 2)

Digonostic Features: Differs from *N. barrisi* and *N. fitzpatricki* in lacking thoracic spines, and tubercles, and having a pygidium with broader, flatter, less spikelike processes and lacks a well defined border.

Occurrence: Lower Rapid.

Remarks: This species differs from *G. alpenensis* by lacking thoracic spines and lacking coarse pustules. *G. aequituberculatus* and *G. arkonensis* of the Traverse Group are strongly pustulose and possess axial nodes. This species most resembles *G. boothi* from the Hamilton Group, but differs by lacking pustules and having only eight or nine axial rings on the pygidium as compared to ten to fourteen in *G. boothi*. This species would appear to be the only known species of *Greenops* to lack coarse pustules, and may be a new species.

Superfamily Phacopacea
Family Phacopidae
Subfamily Phacopinae

Phacops (Emmrich,1839)

Vincular furrow continuous, rear edge sharp, higher than anterior; marginal ridge narrow, doublature concave. Hypostoma elongate, posterior margin with three denticles. Genal angles well rounded,lacking spine. Glabella broadening forward. Cephalon covered with short, stout tubercles.

Phacops rana (Green,1832) (Fig. 2, no. 1)

Diagnostic Features: Can only be confused with *P. iowensis* which is rare and confined to the lower Solon. *P. rana* differs from *P. iowensis* by lacking tubercles on the thorax and pygidium and by posessing a greater amount of facets in its eye. *P. rana norwoodensis* is the subspecies that occurs throughout the Rapid Member. It is possible that *P. rana rana* occurs in the Solon Member. For a complete discussion of *P. rana* subspecies refer to Elderedge (1972).

Occurrence: Upper Solon-Upper Rapid.

Remarks: This well known species is by far the most common Cedar Valley trilobite. Complete specimens are common in the lower part of the Rapid Member.

CONCLUSIONS

The taxonomy of trilobites from the Cedar Valley Group needs further revision. Species described from fragmentary remains such as *C. occidens*, *C. arietinus*, *N. barrisi* and *N. fitzpatricki* need to be redescribed. In addition, trilobites from the lower Solon need to be restudied and have their taxonomy updated. There are three trilobites that are either new species or are previously described species that have not been reported in the Cedar Valley: these are *Greenops* sp., *B. rowi* spp. (?), and *B.* cf. *B. clarus*. Careful study of stratigraphic occurrences shows that Cedar Valley trilobites occur in distinctive assemblages which correlate with the main lithologies of the group. The various species of *Crassiproetus* appear to be the best indicators of stratigraphic horizons and are useful in local correlations.

NOTES ON MIDDLE AND UPPER RAPID ECHINODERM ASSEMBLAGES

Middle and Upper Rapid wackestones/ packstones contain a diverse and well preserved echinoderm fauna. Two distinct assemblages are recognized: 1) Middle Rapid (*Pentamerella*-Upper *bellula* zones) that is equivalent to the *Euryocrinus* and *Hexacrinites* zonules of Strimple (1970); and 2) Upper Rapid (*waterlooensis*), *Strobilocystites* zonule (Strimple, 1970).

At Buffalo, Scott County and in Johnson County Iowa the middle Rapid assemblage is dominated by camerate crinoids (*Megistocrinus*), flexible crinoids (*Euryocrinus*, *Eutaxocrinus*) and blastoids (*Nucleocrinus*, *Placoblastus*). In contrast the upper Rapid assemblage at Curtis Bridge and Mid-River Marina quarries (STOPS 4 & 5) contains common *Melocrinus*, inadunates (*Botryocrinus*, *Decadocrinus*) and cystoids (Strobilocystites). The latter assemblage includes echnoids, starfish and edrioasteroids, but lacks blastoids. Only two of the sixteen crinoid species recognized in the middle Rapid are found in the upper Rapid. Six of twelve crinoid genera make the transition.

The following echinoderm faunal lists are compiled from studies by Thomas (1924), Laudon (1936), Strimple (1970) and Calhoun (1983) as well as the collections cited in this paper.

Middle Rapid Assemblage

- Crinoidea
  - Camerata
    - *Melocrinus tiffanyi* (Wachsmuth & Springer, 1897)
    - *Megistocrinus fitzpatricki* (Thomas, 1924)
    - *Megistocrinus latus* (Hall, 1858)
    - *Hexacrinites occidentalis* (Wachsmuth & Springer, 1897)
    - *Gilbertsocrinus*(?) *strimplei* (Calhoun, 1983)*
    - *Arthrocantha dukukae* (Calhoun, 1983)*
  - Inadunata
    - *Botryocrinus thomasi* (Laudon, 1936)
    - *Synbathocrinus matinutinus* (Hall, 1858)
    - *Synbathocrinus michiganensis*(?) (Kesling & Smith, 1963)
    - *Synbathocrinus belanskii* (Calhoun, 1983)*
    - *Halysiocrinus barrisi* (Worthen, 1875)
    - *Decadocrinus buffaloensis* (Worthen, 1890)
    - *Charientocrinus cracentis* (Calhoun, 1983)*
  - Flexibilia
    - *Euryocrinus kochi* (Calhoun, 1983)*
    - *Eutaxocrinus gracilis* ·(Meek & Worthen, 1865)
    - *Eutaxocrinus* sp.
- Blastoidea
  - *Placoblastus obvatus* (Barris, 1883)
  - *Nucleocrinus bondi* (Thomas, 1924)
  - *Heteroschisma subtruncatus* (Hall, 1858)
- Cystoidea
  - *Strobilocystites calvini* (White, 1876)

Upper Rapid Assemblage

- Crinoidea
  - Camerata
    - *Melocrinus nodosus* (Hall, 1861)
    - *Megistocrinus pernodosus* (Thomas, 1924)
  - Inadunata
    - *Botryocrinus thomasi* (Laudon, 1936)
    - *Botryocrinus cirratus* (Calhoun, 1983)*
    - *Botryocrinus sharae* (Calhoun, 1983)*
    - *Botryocrinus bucalathus* (Calhoun, 1983)*
    - *Decadocrinus crassidactylus* (Laudon, 1936)
    - *Decadocrinus pachydactylus* (Laudon, 1936)
    - *Decadocrinus necomptus* (Calhoun, 1983)*
    - *Corematocrinus spinosus* (Calhoun, 1983)*
    - *Halysiocrinus elephantinus* (Laudon, 1936)
    - *Halysiocrinus septarmatus* (Brower, 1966)
  - Flexibilia
    - *Eutaxocrinus gracilis* (Meek & Worthen, 1865)
- Echnoidea
  - *Devonocidaris* sp.
- Cystoidea
  - *Strobilocystites calvini* (White, 1876)
- Stelleroidea
  - *Devonaster*(?) sp.
- Edrioasteroidea
  - *Agelacrinites* sp.

*(species proposed by Calhoun, 1970)

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THE CORALVILLE AND LITHOGRAPH CITY FORMATIONS OF THE CORALVILLE LAKE AREA

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INTRODUCTION

Sometimes the names of some geographic features are derived from certain rock types in the immediate vicinity. In comparison with many other stratigraphic names, the type areas for the Coralville and Lithograph City formations are apt descriptive terms. For example, in an 1866 lecture at the University of Iowa, Louis Agassiz, a famous geologist, 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 (1941) later 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.

Similarly, at a site in Floyd County in north-central Iowa, high quality limestone for lithographic engraving was quarried in the early 1900's, giving rise to the community of Lithograph City. In 1986, Bunker et al. proposed the term Lithograph City as a formation within the Cedar Valley Group, and designated the old quarry area adjacent to the former town of Lithograph City as the type locality. The Lithograph City Formation was defined (Witzke et al., 1988) for the interval of rocks which lie disconformably between the Coralville Formation below and the Shell Rock Formation or Sweetland Creek Shale above. This interval of strata had previously been assigned to the Coralville by most workers, but does not correlate with any portion of the Coralville sequence in it's type area.

A brief summary of the various members of the Coralville and Lithograph City formations that occur within the Coralville Lake area follows. This summary is an abbreviated version of Witzke et al. (1988).

STRATIGRAPHY

Coralville Formation

The Coralville Formation was deposited during a single transgressive-regressive depositional cycle and is bounded above and below by disconformities or discontinuity surfaces. The formation overlies the Little Cedar Formation, 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, ranging from a maximum thickness of 20 to 25 m in areas of central and northern Iowa, to as thin as 3.9 m in parts of southeastern Iowa.

The Coralville Formation includes a lower fossiliferous carbonate member with an abundant marine fauna (Cou Falls or Gizzard Creek members) and an upper carbonate unit with laminated, brecciated, or evaporitic textures and some restricted-marine faunas (Iowa City Member) (Fig. 1). Within the Coralville Lake area only the Cou Falls and Iowa City members are present.

Cou Falls Member

The type section of the Cou Falls Member is located at the Mid River Marina Quarry, Johnson County, Iowa (STOP 4), 3.5 km southeast of the village of Cou Falls. The member is characterized by fossiliferous fine-grained calcarenite (primarily an abraded-grain packstone) with coral and

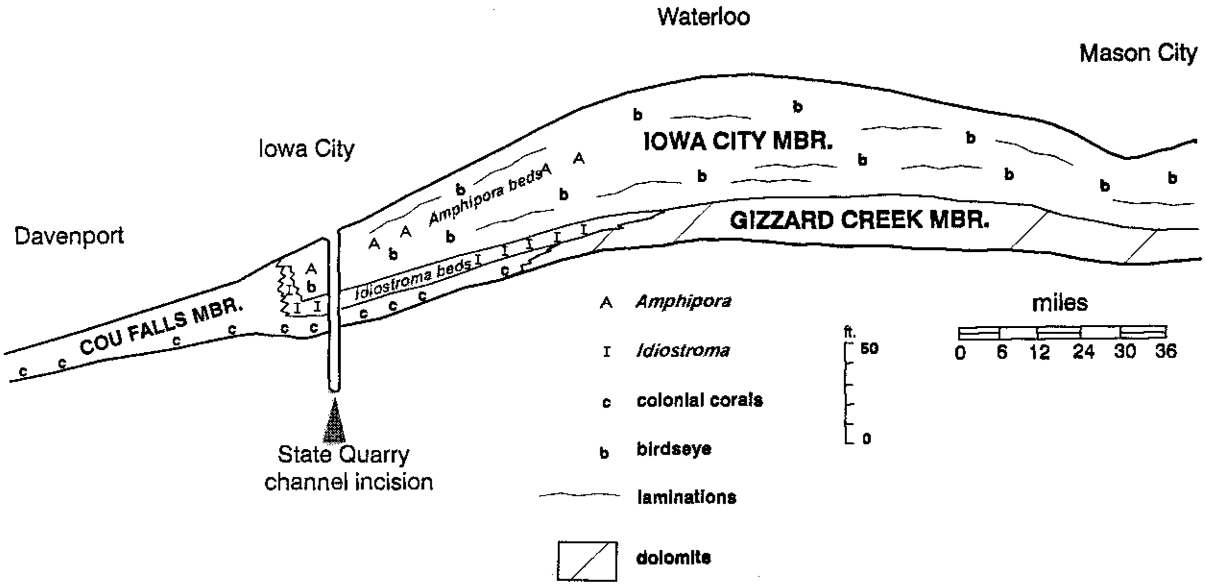


Figure 1. Generalized lithostratigraphic x-section of the Coralville Formation. Base of the Cedar Valley Group was utilized as the datum for the x-section. Relationship of the State Quarry Member, Lithograph City Formation, is depicted in the Iowa City area of the x-section.

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 burrowed discontinuity surface at the top of the Rapid Member, Little Cedar Formation; 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. 1), 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 (Fig. 1). 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.

Faunas. Conodonts of the Cou Falls Member are sparse but include *Icriodus subterminus*, *Mehlina gradata*, and undescribed species of *Polygnathus*; these indicate assignment to the Upper *subterminus* Fauna (Witzke et al., 1985).

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."

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; see also Day this guidebook); *Pseudoatrypa*, *Cranaena*, *Pholidostrophia*, and *Pentamerella* generally dominate. The "*Cranaena* zone" also contains echinoderm debris (rare cups, Calhoun, 1983), common rostroconchs, rare bryozoans, trilobites (*Dechenella*), and calcareous algae and foraminifers (Kettenbrink and Toomey, 1975).

The overlying "*Idiostroma* beds" are characterized by biostromal strata containing branching ("*Idiostroma*") and massive stromatoporoids, colonial (*Hexagonaria*) and solitary rugosans, and favositids. Echinoderm debris decreases in abundance upward, and rostroconchs, gastropods, brachiopods (Day, 1988), and calcareous algae and foraminifers (Kettenbrink and Toomey, 1975) also occur.

The Cou Falls Member east of the Iowa City edge 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, 1982; Witzke et al., 1985; Day, 1988). Lower Cou Falls strata in the eastern area contain a coral and stromatoporoid fauna similar to that in the type area; echinoderm debris, bryozoans (locally abundant), and a different assemblage of brachiopods are present, including *Orthospirifer*, *Independatrypa*, *Strophodonta*, *Schizophoria*, and others (Day, 1988).

Deposition. Initial deposition of the Cou Falls Member buried a widespread submarine discontinuity surface over southeastern Iowa that formed coincident with renewed transgression. Regressive deposits at the top of the Little Cedar Formation (Hinkle Member and "Curtis Bridge" grainstone, see Plocher & Ludvigson, this guidebook for discussion) are overlain by fossiliferous Cou Falls strata along the Hinkle zero edge, further emphasizing the transgressive nature of basal Cou Falls sedimentation. The general upward decline in faunal diversity in the type sequence of the Cou Falls Member suggests a shallowing-upward depositional sequence, which is further verified by the southeastward progradation of tidal-flat and restricted-marine facies of the Iowa City Member over the Cou Falls (Fig. 1). Calcarenitic lithologies of the Cou Falls Member imply that bottom currents winnowed out much of the mud during deposition, and overturned coral heads and abraded-grain textures attest to the presence of vigorous bottom currents. Kettenbrink (1973) suggested a position generally above wave base for deposition of lower Coralville sediments in the type area of the Cou Falls Member, although storm and tidal currents may have been involved as well. A general decrease in the abundance of corals and stromatoporoids (especially branching forms) southeast of the type area may be due to slightly deeper depositional environments in that direction. Iowa City peritidal and supratidal facies are apparently replaced by open-marine subtidal facies of the upper Cou Falls (upper Coralville Formation) in southeastern Iowa (Fig. 1).

Iowa City Member

The type locality of the Iowa City Member was designated at the old Hutchinson Quarry on the University of Iowa campus, Iowa City, Johnson County, Iowa. This interval was previously named the Lucas Member (Keyes, 1912) and later the Hutchinson Member (Keyes, 1931), in each case using the same type section, but both names were later found to be preoccupied. The member is characterized by a diverse assemblage of lithologies that commonly share significant lateral facies variations over short distances. The Iowa City 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 the northern area, and some beds are locally sandy. Evaporite molds 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 (Fig. 2). 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 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 (Fig. 1). The edge of the Iowa City Member trends south-southwest from the type area (Fig. 2), and the member is absent in southeastern Iowa and adjacent parts of northeastern Missouri and western Illinois.

Faunas. 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. Fossiliferous calcilutites and some calcarenites interbed with the 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 Iowa City Member contains abundant branching stromatoporoids ("*Amphipora* bed" of Kettenbrink, 1973) in the type area, and this interval probably correlates with stromatoporoid-rich strata to the north (Fig. 1) . Fossiliferous calcilutites have also yielded brachiopods (*Athyris*), crinoid debris (locally in northern sections), rare rostroconchs, gastropods, ostracodes, spirorbids, and calcareous algae and foraminifera (Kettenbrink and Toomey, 1975). Faunal diversity generally decreases upward in the Iowa City Member sequence in the type area (Kettenbrink, 1973).

Deposition. The Iowa City Member is interpreted to have been deposited in restricted-marine, intertidal, and supratidal settings (Kettenbrink, 1973; Witzke, 1984; Witzke et al., 1988). Abundant desiccation features ("birdseye" and mudcracks) and vadose fabrics indicate periodic subaerial exposure of an extensive mudflat facies. Complex lateral facies changes suggest that deposition of the member was characterized by a mosaic of tidal-flat and shallow restricted-marine environments, in part intertidal. Mudflat facies apparently prograded to an intracratonic shelf break in southeastern Iowa (Fig. 1) during the regressive phase of upper Coralville (Iowa City) deposition. Evaporitic depositional conditions are indicated by gypsum-anhydrite in central Iowa (Fig. 2) and prominent breccias (probably formed by evaporite solution-collapse processes) in northern Iowa. Evaporites probably were deposited in sabkha or salina settings in the restricted interior region of the Iowa Basin.

Low faunal diversity within the member may be due to salinity stresses during deposition (Kettenbrink, 1973). The absence or scarcity of many fossils commonly present in more stenohaline faunas of the Cedar Valley (especially echinoderms, bryozoans. trilobites, and rugosans) lends credence to this interpretation. Fossiliferous strata, usually stromatoporoid-rich, occur in the middle part of the Iowa City Member ("*Amphipora* beds"; Fig. 1) along the outcrop belt for 200 km, and, if correlative, may suggest that a minor transgression occurred during the middle part of upper Coralville sedimentation. The entire region covered by the Iowa City Member was apparently exposed to subaerial processes during maximum marine offlap (see Ludvigson, this guidebook, for a discussion of diagenesis relating to the Iowa City offlap). An erosional surface was developed at that time, and incison of up to 20 m is documented beneath the State Quarry Member near the shelf margin of the Iowa City Member in Johnson County, Iowa (Fig. 1).

Lithograph City Formation

The Lithograph City Formation was deposited during a single transgressive-regressive depositional cycle (Witzke et al., 1988), and is bounded above and below by disconformities or discontinuity surfaces. The formation overlies the Coralville Formation, and where capped by younger Devonian strata is variably overlain by the Shell Rock, Sweetland Creek, or Lime Creek formations. The Lithograph City Formation ranges from about 20 to 36 m in thickness in northern and central Iowa, and is thinner to the southeast where it ranges from 0 to 12 m in thickness.

The Lithograph City Formation in northern Iowa includes limestone, shale, and dolomite, variably fossiliferous, laminated, or brecciated; evaporites are present in central Iowa. Three members of the formation are recognized in this area (Osage Springs, Thunder Woman Shale, and Idlewild; Bunker et al., 1986). The formation is dominated by fossiliferous limestone, dolomite, and shale in southeastern Iowa, which consists of two distinctive facies (the State Quarry Member in eastern Iowa and the Andalusia Member in southeastern Iowa and adjacent areas of northeastern Missouri and western Illinois; ibid.). Within the Coralville Lake area only the State Quarry and Andalusia members have been observed.

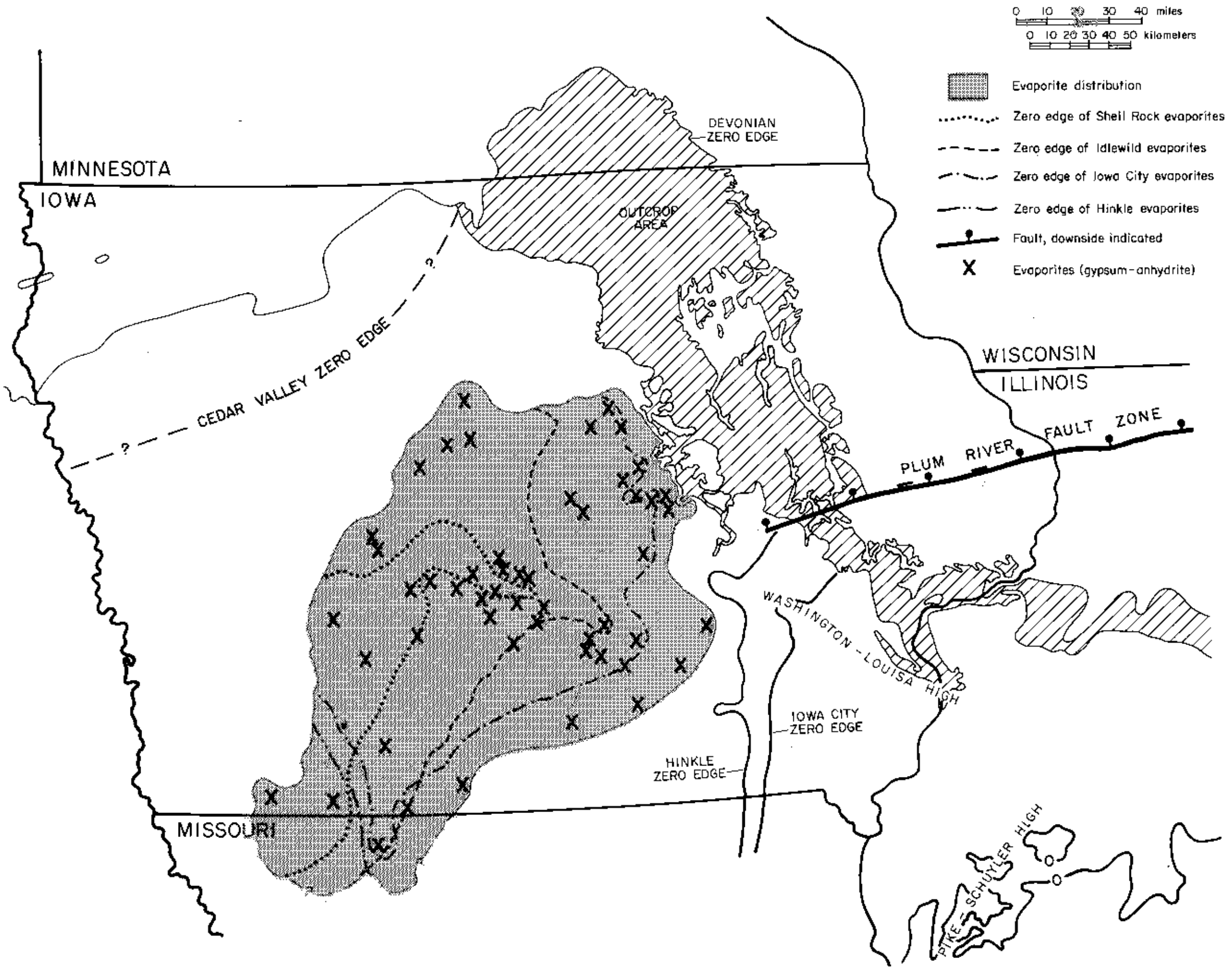


Figure 2. Evaporite distribution map of the Cedar Valley Group (Witzke et al., 1988).

State Quarry Member

The "State Quarry limestone" was named by Calvin (1897) for exposures at the old state quarry in the Iowa River valley (present-day Coralville Lake) 10 km north of Iowa City in Johnson County, Iowa. Rock was first quarried there for construction of the Territorial Capitol in Iowa City beginning in 1840. The unit was assigned member status within the Lithograph City Formation based on conodont and brachiopod biostratigraphy, stratigraphic position, and physical evidence for intergradation with the Andalusia Member in a core 21 km southeast of the type locality (Bunker et al., 1986). The State Quarry Member is restricted to Johnson County 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) (Figs. 1, 3). 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 to 12 m.

Faunas. The conodont fauna of the State Quarry Member includes *Pandorinellina insita*, *Polygnathus angustidiscus*, *P. norrisi*, and *Icriodus subterminus* (Watson, 1974; Witzke et al., 1988); it is assigned to the *insita* Fauna, and correlated with the Lowermost *asymmetricus* Zone. Other conodonts are 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; see also Day this guidebook), including *Allanella*, *Independatrypa*, *Radiatrypa*, and *Ladogioides*. Branching and massive stromatoporoids, solitary rugosans, favositids, auloporids, gastropods, nautiloids, spirorbids, ostracodes, trilobites, calcareous algae and foraminifera, and fish debris (placoderms and dipnoans) are noted (Watson, 1974).

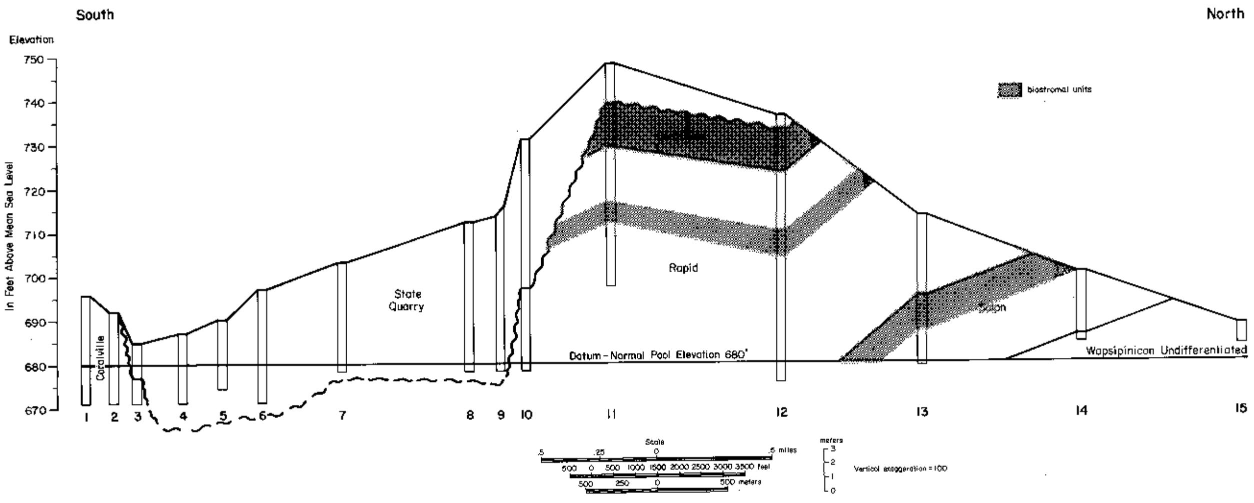
Deposition. The State Quarry Member is developed locally near the shelf margin of the underlying Iowa City Member, Coralville Formation (Fig. 1). Channels were incised at that position, apparently during the erosional episode that followed deposition of upper Coralville sediments. Sedimentation resumed during a subsequent regional transgression (T-R cycle IIb of Witzke et al., 1988), and shallow-marine sediments of the State Quarry Member were deposited within the channels at that time (see Ludvigson, this guidebook, for a discussion of the diagenetic relationships between the Iowa City and State Quarry members). Abraded grain calcarenites and common crossbedding within the member indicate relatively agitated deposition within the central channel areas. The State Quarry Member probably represents a marine tidal-channel facies (Watson, 1974), which developed within a series of erosional channels that were cut during subaerial exposure of the Coralville Formation along the intracratonic shelf margin (Bunker et al., 1986).

Andalusia Member

The Andalusia Member was defined by Bunker et al. (1986) and Witzke et al. (1988) as a distinctive unit encompassing the Lithograph City Formation in southeastern Iowa, and adjacent parts of northeastern Missouri and western Illinois. The type locality is designated at Buffalo Quarry, Scott County, Iowa, 1.3 km north of Andalusia Slough in the Mississippi River Valley (see Witzke et al., 1985). The Andalusia Member was assigned to the Coralville Member by most previous workers, and was included in the Lime Creek Formation in the subsurface of southeastern Iowa by Dorheim et al. (1969, p. 6). Klug [1982, p. 12-13, 382.9-404.5 ft (116.0-122.6 m)] included the interval in the Maple Mill Shale. Biostratigraphic relations and stratigraphic position indicate that it is a post-Coralville stratigraphic unit of the Cedar Valley Group, and is therefore included in the Lithograph City Formation.

The Andalusia Member 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 one-third of the member in the 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.

Faunas. 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). Uppermost strata of the member have yielded *Ancyrodella rugosa*, *A. africana*, *A. alata* (late form), *Polygnathus asymmetricus*, *P. dubius*, *I. subterminus*, and *M. gradata*; these forms indicate assignment to the upper part of the Lower *asymmetricus* Zone (ibid.). Therefore, the position of the Middle/Upper Devonian boundary, as recognized by the Devonian Subcommission, occurs at an undefinable position within the Lithograph City Formation. Brachiopods of the Andalusia Member include *Strophodonta*, *Independatrypa*, *Schizophoria*, *Allanella*, and *Tecnocyrtina*; *Orthospirifer* and *Cranaena* occur in the upper beds (faunal list in Day, 1988). Echinoderm debris is common to abundant, and bryozoans, bivalves, gastropods, rostroconchs, nautiloids, and fish debris are noted in some beds. Biostromal



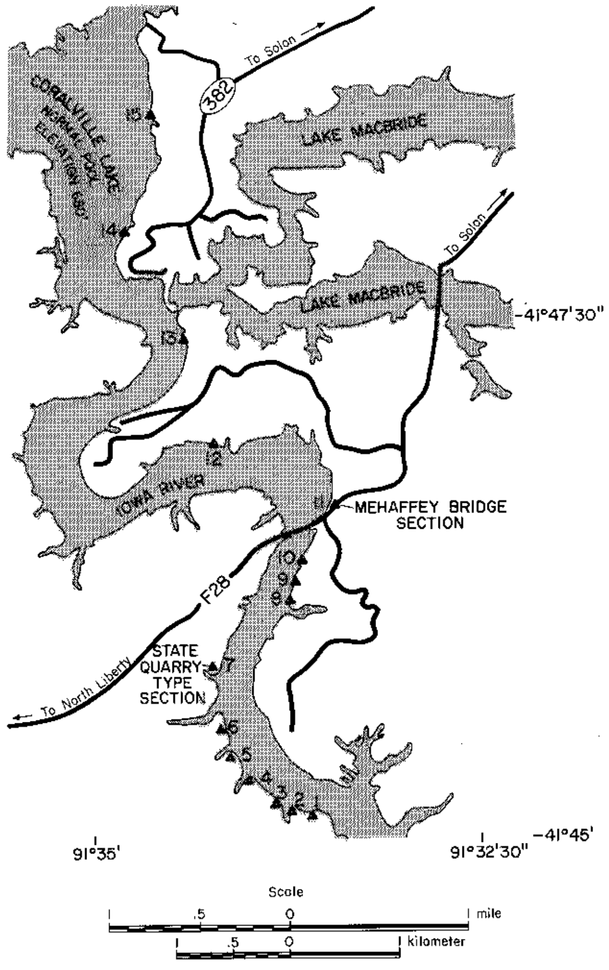


Figure 3. Simpilified x-section of the State Quarry relationship to the underlying Coralville and Little Cedar formations in the Coralville Lake area (Bunker & Witzke, 1987). Map depicts stratigraphic sections along the shore face of Coralville Lake that were utilized in construction of the x-section.

units in the upper Andalusia Member are variably dominated by solitary rugosans (but with some favositids) or massive stromatoporoids.

Deposition. The Andalusia Member is interpreted to have been deposited entirely within open-marine subtidal environments. Brachiopod-dominated faunal associations in the lower member are succeeded by coral and stromatoporoid biostromes in the upper part, and a general shallowing-upward depositional sequence is inferred. Middle and upper Andalusia strata are replaced by mudflat and restricted-marine facies of the Idlewild Member to the northwest. Mudflat facies of the Idlewild prograded southeastward to an intracratonic shelf margin during a major regional regression in a manner analogous to deposition of the Iowa City Member in the underlying Coralville Formation. Open-marine facies of the Andalusia Member were deposited in the region downslope from the intracratonic shelf margin, and consistently deeper marine environments are indicated in southeastern Iowa compared to northern and central Iowa during the deposition of the Lithograph City Formation.

"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 spores 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 tentatatively assigned to the Cerro Gordo Member of the Lime Creek Formation.

The recovery of *Palmatolepis semichatovae* (Müller & Müller, 1957, p. 1101-1102, Pl. 142, fig. 9; see synonymy in Klapper & Lane, 1985) 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. 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 noted tributary from its opening at Coralville Lake, a normal stratigraphic succession from basal Cou Falls through the Iowa City members is encountered with occassional 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 litho-stratigraphic 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.

An examination of the combined geologic and structure map of the Coralville area [see map (fig. 6) in Plocher and Bunker, this guidebook] 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 both in the fact that it is preserved in paleotopographic lows cut into the Coralville and Little Cedar formations, and because of its location within a local syncline.

SUMMARY

Epicontinental seaway shelves are generally characterized by repetitive episodes of progradation, which are punctuated by periods of transgression and subsequent flooding of the seaway margins. These episodes are generally recognized along the epicontinental shelves as transgressive-regressive (T-R) cycles. The basic stratigraphic framework of the Middle Devonian Wapsipinicon and Cedar Valley groups are defined as a series of depositional (T-R) cycles (Witzke et al., 1988), which occur along the western margin of the Middle to Late Devonian Chattanooga Sea [sometimes referred to as the Catskill Sea; the term Chattanooga Sea is used in lieu of Catskill, to avoid confusion with the Catskill Clastic Shelf located along the eastern margin of the seaway]. Repetitive T-R sequences in carbonate rocks of the Upper Midwest define an area which has been termed the Midcontinent Carbonate Shelf by Slingerland (1986), who modelled tidal effects in the Late Devonian seaway. Current descriptive terminologies for classic carbonate shelves appear to be inadequate in their treatment of intracratonic seaways during the Paleozoic. Therefore, usuage of the terms "inner", "middle", and "outer" shelf are only used in this paper in a general sense to imply shallower to deeper water trends within the epicontinental seaway. 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 the Coralville Lake area occur along the general trend of such a shelf margin, with deeper ("middle" shelf) environments to the east and southeast.

The basic T-R cycles of the Cedar Valley Group (Witzke & Bunker, 1984) 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 (see Fig. 2) record deposition in shallow, restricted subtidal and tidal-flat settings during the regressive (progradational) phase.

Figure 1 shows a generalized cross-sectional view of a transect across the Midcontinent Carbonate Shelf area during Coralville deposition. The main features of the Coralville cycle include: 1) the base of the cycle is generally flat in upper reaches (shoreward) of the shelf and slopes gently seaward in the lower (basinward) portions, 2) the basal transgressive units (Cou Falls and Gizzard Creek members) are thin in comparison to the thickness of the overall depositional cycle, and 3) the main sediment thickness in the depositional wedge is developed upward and progradationally in the regressive Iowa City Member. The constructional topography of the Coralville Formation, noted by its thickness variations, was probably influenced by depositional patterns inherited from the underlying Little Cedar Formation (note similarity of zero edges of the Hinkle and Iowa City members in Fig. 2). The Coralville depositional cycle was completed with the progradation of restricted-marine and tidal-flat sediments to an "inner" shelf margin in the Iowa City region (note position of Iowa City zero edge on Fig. 2). The "inner" shelf was subaerially exposed (see Ludvigson, this guidebook, for a discussion of the diagenetic features of the uppermost Coralville Formation) as the seas withdrew to the east-southeast, allowing for development of erosional channels and vadose fabrics near the Iowa City zero edge. Then, the eroded carbonate terrain of the uppermost Coralville was transgressed by a clear tropical sea represented by the State Quarry Member of the Lithograph City Formation in the erosional channels (Figs. 1, 3).

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MIDDLE-LATE DEVONIAN (LATE GIVETIAN-EARLY FRASNIAN) BRACHIOPOD FAUNAS AND BIOSTRATIGRAPHY OF THE CORALVILLE AND LITHOGRAPH CITY FORMATIONS OF EASTERN IOWA

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INTRODUCTION

This study outlines the composition and distribution of the late Givetian and earliest Frasnian brachiopod faunas of the Coralville and Lithograph City formations in eastern Iowa (Figs. 1 & 2). Particular attention is focused on the Coralville and Lithograph City faunas as seen in outcrops and quarry exposures in the Johnson and Scott County areas. Correlations of these units, based on their brachiopod and conodont faunas, are summarized.

CORALVILLE FORMATION

The general stratigraphic relationships of members of the Coralville Formation are shown in Figures 3 and 4 (see also Bunker and Witzke, this guidebook). In the Johnson County area (Figs. 2 & 4) the Coralville is divided into the basal Cou Falls Member, and the overlying Iowa City Member. The Cou Falls (Fig. 4) consists mostly of subtidal open-marine skeletal carbonates representing the transgressive phase, and the shallow subtidal and peritidal carbonates of the Iowa City Member represent the regressive phase of Coralville deposition. Strata of the Coralville Formation represent T-R Cycle 4 of the Iowa Devonian sea-level curve, and part of the Devonian eustatic T-R Cycle IIa of Johnson et al. (1985) as shown in Figure 2.

The brachiopod fauna of the Coralville Formation consists of 25 species (Table 1; Day, 1988). In Johnson County, the Cou Falls Member fauna consists of at least 17 species (Table 1). Most of these first appear in the older faunas of the Little Cedar Formation. Aside from scattered *Athyris vitatta* is the only species known in the Iowa City Member, Coralville Formation (Day, 1988). All of the brachiopod species in the Coralville fauna were described in various works by Stainbrook (1938-1943).

Stainbrook (1941) 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 Stainbrook's (1941) *Cranaena* and *Stromatopora* are now assigned to the Cou Falls Member (Witzke et al., 1988). Day (figs. 1 & 4, 1988) described six brachiopod faunas from the Coralville Formation in Iowa. These are the *Tecnocyrtina*, lower *Athyris*, *Cranaena*, *Elita*, *Strophodonta*, and upper *Athyris* faunas. These correspond to different biofacies that occuppied various regimes (restricted-, open-marine, distal subtidal shelf) of the Coralville seaway during the late Givetian. The *Cranaena* and *Elita* faunas occur in the Cou Falls Member in the Johnson County area and represent open-marine and partially restricted-marine shelf assemblages, respectively. The *Strophodonta* and upper *Athyris* faunas occur in the Coralville in the Scott County area in extreme eastern Iowa, and represent distal subtidal shelf faunas.

The Cou Falls Member in Johnson County contains the the upper *subterminus* conodont fauna (Fig. 3; Witzke et al., 1985; 1988). The lower *subterminus* Fauna occurs in the upper Rapid Member of the Little Cedar Formation (Fig. 2; Witzke et al., 1988). The upper *subterminus* Fauna consistently underlies strata of the Lithograph City Formation that contain the *Pandorinellina insita* Fauna (State Quarry Member in Johnson County). The upper *subterminus* Fauna of the Coralville probably correlates with the upper part of the *disparilis* Zone in Central Nevada (Johnson et al., 1980; Johnson et al., 1985).

TABLE 1. 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: CF = Cou Falls Mb., IC = Iowa City Mb., GC = Gizzard Creek Mb.; Scott County-Buffalo Quarry, LC = lower Coralville Fm., UC = upper Coralville Fm. (After table 1 of Day, 1988)

	OCCURRENCE				
CLASS-INARTICULATA					
Petrocrania famelica				LC	
CLASS ARTICULATA-ORDER ORTHIDA					
Schizophoria lata Stainbrook **	CF			LC	
STROPHOMENIDA					
Pholidostrophia iowensis (Owen)	CF		GC		
Productella? belanskii Stainbrook	CF				
Schuctertella iowensis Stainbrook	CF		GC		
Strophodonta plicata (Hall) *	CF		GC		
S. (*S.*) *parva* (Owen)	CF			LC	
S. (*S.*) *randalia* (Stainbrook)	CF			LC	UC
RHYNCHONELLIDA					
Atribonium subovata (Savage) *	CF		GC	LC	
SPIRIFERIDA					
Athyris vitatta Hall **	CF		GC	LC	UC
Cyrtina triquerta Hall	CF			LC	
C. umbonata Hall					UC
Elita johnsonensis (Stainbrook)	CF	IC	GC		
Eosyringothyris aspera (Hall)					UC
Orthospirifer euruteines (Owen)	CF			LC	
Tecnocyrtina missouriensis (Swallow) *			GC		
Tylothyris subvaricosa (Hall)	CF		GC		
Independatrypa independensis (Webster) **					
Desquamatia waterlooenssis (Webster)	CF		GC	LC	
Pseudoatrypa rotunda (Stainbrook)				LC	UC
PENTAMERIDA					
Pentamerella dubia Hall *	CF				
P. laeviscula Hall	CF	IC	GC		
TEREBRATULIDA					
Cranaena iowensis (Calvin) *-**	CF	IC	GC	LC	
Cranaena subovata Savage *	CF			LC	

Cranaena Fauna

The brachiopod fauna in the lower part of the type Cou Falls Member (*Cranaena* Zone of Stainbrook, 1941) in the Johnson County and surrounding areas is called the *Cranaena* Fauna (Table 1; Day, 1988). The species *Strophodonta (S.) plicata*, *Atribonium subovata*, *Pentamerella dubia*, and *Cranaena iowensis* are restricted to the *Cranaena* Fauna (Table 1). Brachiopod assemblages typical of the *Cranaena* Fauna occur in the basal strata of the Gizzard Creek Member in Benton County at the Garrison Quarry. The Gizzard Creek fauna at the Garrison Quarry contains: *Elita johnsonensis*, *Orthospirifer euruteines*, *Athryis vitatta*, *Desquamatia waterlooensis*, *Pholidostrophia iowensis*, *Strophodonta plicata*, *Cranaena iowensis*, and *Atribonium subovata*.

Elita Fauna

The *Elita* Fauna is a low diversity brachiopod assemblage that occurs in association with the tabulate coral and stromatoporoid fauna of the *Stromatopora* Zone of Stainbrook (1941), now referred to as the *Idiostroma* Zone (Fig. 4; Table 1; Glenister & Heckel, 1984), of the upper part of the Cou Falls Member of the Coralville in Johnson County. This fauna contains *Elita johnsonensis*, *Pentamerella laeviscula*, and *Cranaena iowensis*.

Strophodonta Fauna

The *Strophodonta* Fauna (Table 1) occurs in the lower Coralville Formation at the Buffalo Quarry in Scott County (Fig. 4) in strata of the lower skeletal calcarenite unit of Witzke et al. (1985; 1988). The *Strophodonta* Fauna contains *Cyrtina triquerta*, *Orthospirifer euruteines*, *Athyris vitatta*, *Independatrypa independensis*, *Strophodonta (S.) parva*, *Schizophoria lata*, *Atribonium subovata*, *Cranaena iowensis*, and *C. subovata*. This fauna correlates with the *Cranaena* and *Elita* faunas of the Cou Falls Member in Johnson County (Fig. 4; Day, 1988).

upper *Athyris* Fauna

Athyris vitatta and *Strophodonta randalia* are common to the faunas of the lower and upper units of the Coralville Formation. The upper units of the Coralville Formation at Buffalo Quarry (Fig. 4) were referred by Udden (1899) as the *Athyris vitatta* beds, and also contain *Eosyringothyris aspera* and *Cyrtina umbonata*. The *Athyris* Fauna (Table 1) of the upper Coralville Formation at Buffalo represents an offshore facies of the restricted subtidal and peritidal facies of the Iowa City Member in the Johnson County area (Figs. 3 & 4).

LITHOGRAPH CITY FORMATION

The regional stratigraphic relationships of the Lithograph City Formation are shown in Figures 1, 3, and 5. The Lithograph City Formation in eastern Iowa includes the State Quarry Member in the Johnson County area in east-central Iowa, and the Andulusia Member in extreme eastern Iowa.

The State Quarry Member consists of a variety of grain-supported skeletal carbonate lithofacies interpreted as a tidal channel sequence, and contains interbeds in places of subtidal quiet water mud-rich facies. The Andaulusia Member in extreme eastern Iowa (Fig. 5) represents more mud-rich deposits that accumulated in more distal parts of the Lithograph City seaway, essentially mirroring the earlier regional pattern of Coralville deposition. Strata of the Lithograph City Formation represent a single depositional sequence (Fig. 2) corresponding to T-R Cycle of 5 of Witzke et al. (1988) and Devonian eustatic T-R Cycle IIb of Johnson et al. (1985).

Three major faunas occur in the State Quarry and Andalusia members of the Lithograph City Formation in eastern Iowa. These include the *Ladogioides* Fauna from the State Quarry, and the lower *Strophodonta* and *Orthospirifer* faunas from the Andalusia Member in Scott County (Table 2; Day, 1988).

State Quarry Member

The State Quarry Member and parts of its fauna were first described by Calvin (1897). Later, Stainbrook and Ladd (1924) described most of its brachiopod fauna. Brachiopods occur in nearly all lithologies of the State Quarry Member where it is known to outcrop in Johnson County (Watson, 1974; Day, 1986, 1988). A variety of different assemblages occur in various lithofacies of the State Quarry Member (Watson, 1974), and were described collectively as the *Ladogioides* Fauna (Day, 1988).

Ladogioides Fauna

The *Ladogioides* Fauna (Table 2) occurs in strata representing tidal channel-fill sediments deposited during the transgressive phase of Lithograph City deposition (Bunker et al., 1986). Various brachiopod assemblages occur in different lithofacies of the State Quarry Member in the Coralville Lake area.

At Mehaffey Bridge, Indian Cave, and the State Quarry type locality (Fig. 5B section TSC, Old State Capitol Quarry), skeletal grainstones contain assemblages dominated by *Radiatrypa rugatula*, *Cranaena depressa*, *Ladogioides solon*, *Allanella annae*, *Cyrtina* sp. aff. *C. triquetra* with minor occurrences of *Schizophoria athabaskensis*, and *Floweria altirostris*. At Mehaffey Bridge, the uppermost skeletal mudstones of the State Quarry contain a fauna composed almost exclusively of *Independatrypa independensis*. *Spinatrypina* occurs in assemblages dominated by either *Allanella* or gastropods and amphiporid stromatoporoids in skeletal packstones at State Quarry exposures on the west side of Coralville Lake southwest of Mehaffey Bridge.

At Meyers Quarry southwest of Solon *Allanella annae* and *Variatrypa* (*R.*) *rugatula* occur in the lower skeletal-rich grainstones, and *I. independensis* in the upper mudstones of the State Quarry (Watson, 1974). Just to the south at the Vanourney Quarry *Eosyringothyris occidentalis* has been reported from skeletal packstones, although no precise stratigraphic locality was mentioned in Watson's (1974, p. 85) discussion.

Tecnocyrtina curvilineata (Hall) occurs with *Strophodonta* (*Strophodonta*) *iowensis* and *Independatrypa independensis* in the lower two meters of the State Quarry Member in the core section in Mid-America Pipeline Company Hole # 3, southeast of Iowa City in Johnson County. This species also occurs in the *Strophodonta* Fauna of the lower Andalusia Member in Scott County, Iowa.

Andalusia Member

The brachiopod fauna of the Andalusia Member (Table 2) consists of 11 species, and is dominated by *Strophodonta* (*Strophodonta*), *Schizophoria*, and *Independatrypa*. This unit is best exposed at the Davenport Cement Co. Quarry at Buffalo (Fig. 5C), in Scott County, Iowa (Witzke et al., 1985; 1988; Bunker et al., 1986). Day (1986, 1988) informally divided the Andalusia Member into the "lower" and "upper" Andalusia Member. Hall (1858) and Stainbrook (1938a, 1940a, 1942a, 1943b) described most of the fauna known from both the "lower" and "upper" Andalusia Member at exposures near Buffalo and Pine Creek to the east along the Mississippi River.

lower *Strophodonta* Fauna

At the Davenport Cement Co. Quarry in Buffalo, Iowa, the "lower" Andalusia Member (Fig. 5) contains a brachiopod fauna with abundant *Strophodonta* (*S.*) *iowensis*, *Independatrypa independensis*, and *Schizophoria lata*. *Athyris vittata*, *Tecnocyrtina curvilineata*, *Allanella annae*, and *Eosyringothyris occidentalis* occur as minor elements, weathering from shales and argillaceous skeletal packstones. Hall (1858) and Stainbrook (ibid.) nearly all of the "lower" Andalusia species from the lower units near the base of the Andalusia Membeer (units 30 & 32 of Witzke et al., 1985; 1988). Stainbrook (1943a) referred to the shale and the fauna of unit 32 as the "*Strophodonta iowensis* zonule".

Orthospirifer Fauna

The "upper" Andalusia Member (Fig. 5) consists of thick-bedded and massive dolomites interbedded with shaley biostromal units, and contain a low-diversity brachiopod fauna (Table 2). It is from the "upper" Andalusia that Hall and Stainbrook collected *Orthospirifer capax*. In addition, *Strophodonta* (*S.*) sp. A, *Cranaena* sp., and large specimens of *I. independensis* occur in these strata (Day, 1988). Witzke et al. (1988) listed a conodont fauna containing important species of *Ancyrodella* from the "upper" Andalusia Member at Buffalo.

BIOSTRATIGRAPHY

Strophodonta plicata Zone

This zone was defined on the faunas the Coralville Formation by Day (1988). The base of the zone is defined by the first appearance of *Strophodonta plicata* (Hall) in the lowermost Cou Falls Member at the Mid River Marina Quarry in Johnson County, and further characterized by the first appearances of *Strophodonta randalia*

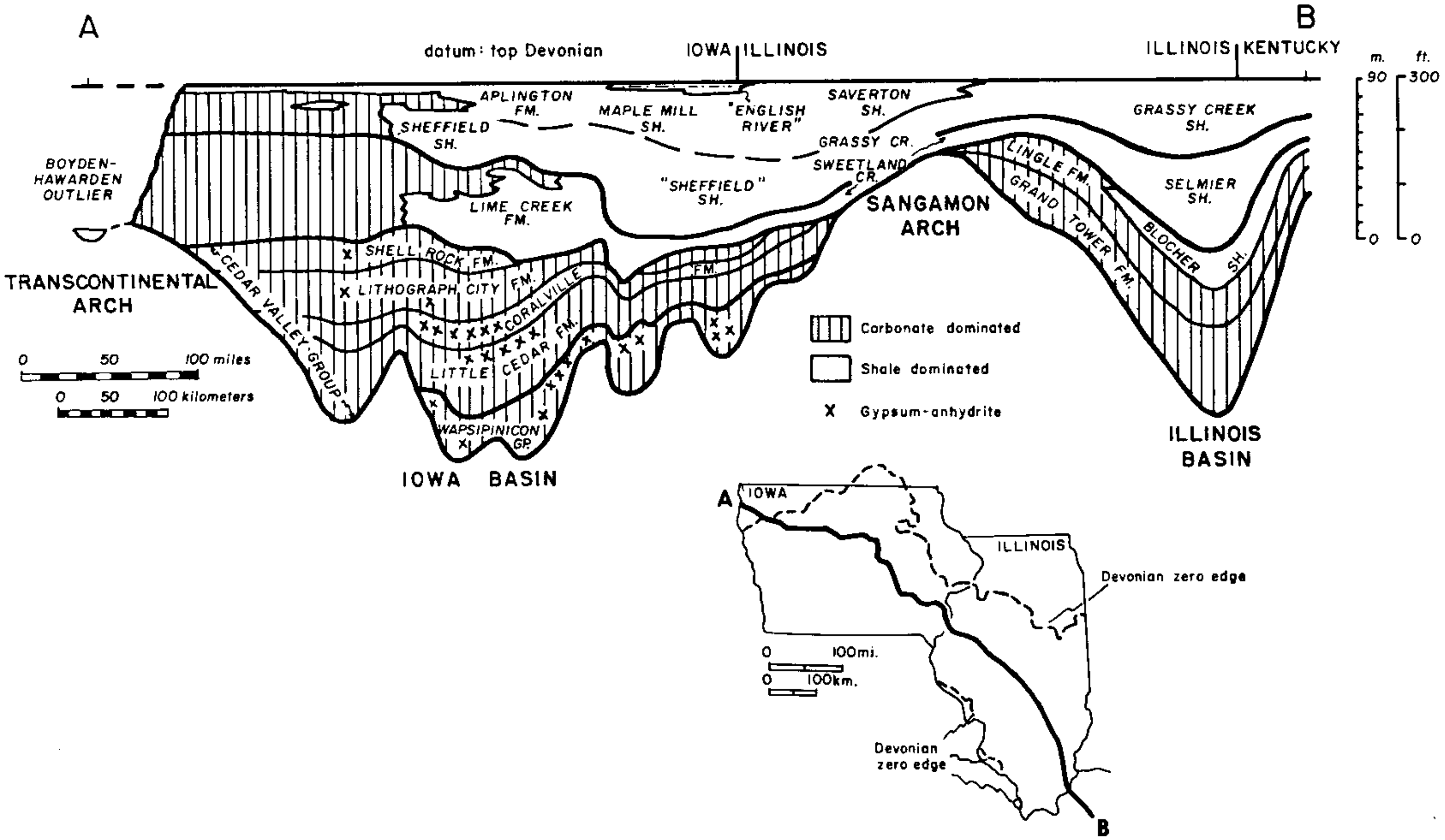

Figure 1. Cross-section of the Middle and Upper Devonian strata of the Iowa and Illinois basins and major tectonic features in the area of the U. S. Midcontinent platform (after fig. 4 of Witzke et al., 1988; fig. 1, Day, in press).

TABLE 2. 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. First appearance of species in the Lithograph City designated by *, species ranging into the Shell Rock Formation designated by **. Modified from table 2 of Day (1988). The symbol sp. designates an undescribed species.

	OCCURRENCE			
ORTHIDA				
Schizophoria lata Stainbrook	OS			A
S. aff. *S. athabaskensis* Norris *			SQ	
RHYNCHONELLIDA				
Ladogioides solon (Thomas & Stainbrook) *			SQ	
STROPHOMENIDA				
Strophodonta (*Strophodonta*) *iowensis* (Stainbrook) *	OS		SQ	A
S. (*S.*) sp. A *-**		I		A
Floweria altirostris (Stainbrook & Ladd) *			SQ	
F. sp.	OS	I		
SPIRIFERIDA				
Allanella allani (Warren) *	OS	I		
A. annae (Stainbrook) *			SQ	A
Cyrtina sp., aff. *C. triquetra* Hall*			SQ	
Eumetria? sp.			SQ	
Orthospirifer capax (Hall) *				A
Eleutherokomma jasperensis Warren *-**		I		
Eosyringothyris occidentalis Stainbrook *			SQ	A
Tecnocyrtina curvilineata (Hall) *				
Independatrypa independensis (Webster)	OS	I	SQ	A
Pseudoatrypa? *percrassa*? (Crickmay) *		I		
Spinatrypina cf. *S. augusticostata* Johnson & Trojan *			SQ	
Variatrypa lineata (Webster) = *V. clarkei* (Warren) *		I		
V. rugatula (Stainbrook & Ladd) *			SQ	
Athyris simplex Stainbrook & Ladd *			SQ	
A. vittata Hall	OS	I		A
A. v. buffaloensis Stainbrook				A
PENTAMERIDA				
Gypidulina sp.		I		
TEREBRATULIDA				
Cranaena depressa Stainbrook & Ladd *			SQ	
C. infrequens Belanski		I		
C. sp. *				A

(Stainbrook), *Cranaena iowensis* (Calvin), and *Atribonium subovata* (Savage). *Tecnocyrtina missouriensis missouriensis* appears in the same stratigraphic position in the lowermost units of the Gizzard Creek Member in Blackhawk County and correlates with the base of this zone (Day, 1988). The lowermost Coralville strata containing the *Strophodonta* Fauna at the Buffalo Quarry in Scott County are also correlated with the base of this zone (Day, 1988).

As mentioned earlier, the Coralville Formation contains the upper *subterminus* conodont fauna (Bunker & Klapper, 1984; Witzke et al., 1985; 1988). Conodonts of the upper *subterminus* Fauna occur with brachiopods of the *Cranaena* and *Strophodonta* faunas in Johnson and Scott counties, respectively. The upper *subterminus* Fauna of the Coralville Formation was correlated (Bunker & Klapper, 1984; Witzke et al., 1988) with a position in the upper *disparilis* Zone as defined by Ziegler and Klapper (1981, 1982a, b).

Day (1988) correlated the *Strophodonta plicata* Zone of the Coralville Formation with Faunal Interval 27 of the Nevada Devonian brachiopod succession (lower *Tecnocyrtina* Fauna of Johnson & Trojan, 1982), based on the occurrence of *Tecnocyrtina missouriensis* in the Gizzard Creek Member of the Coralville Formation. 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.

Fraunfelter (1968) listed, and illustrated (1974) *Cranaena iowensis, Cyrtina missouriensis, Strophodonta plicata*, *Strophodonta parva* from the *Atrypa missouriensis* and *Stropheodonta* biofacies in the Cedar Valley Formation of Missouri. The foregoing species listed from these "biofacies" allow tentative correlation with the *Strophodonta plicata* Zone of Iowa. Day (1988) correlated the *Strophodonta plicata* Zone with the fauna of the "argillaceous limestone beds" of the lower Point Wilkins Member of the Souris River Formation based on the conodont fauna reported by Norris et al. (1982).

Strophodonta iowensis Zone

The base of this zone is defined by the first occurrence of *Strophodonta* (*S.*) *iowensis* (Stainbrook) with *Allanella annae* (Stainbrook) in unit 30 (Witzke et al., 1985, fig. 5) of the Andalusia Member at the Buffalo Quarry (Davenport Cement Co. Quarry) in Scott County, Iowa (Day, 1988). The base of this zone correlates with the lowermost State Quarry Member containing the *Ladogioides* Fauna, which contains both *Strophodonta iowensis* and *Allanella annae*. *Tecnocyrtina curvilineata* (Hall) occurs in the lower parts of both the Andalusia and State Quarry members in eastern Iowa.

In Nevada, the brachiopods *Tecnocyrtina fissiplicata*, *Ladogioides pax*, *Allanella layeri*, *Variatrypa* (*R.*) *klukasi*, and *Spinatrypina augusticostata* occur with the conodont *Pandorenellina insita* in strata in the Antelope Range of central Nevada (Johnson & Trojan, 1982). Johnson and Trojan correlated these strata with the upper *disparilis* Zone (= Lower *dengerli* Zone of Johnson et. al., 1980), and is considered equivalent to the Lowermost *asymmetricus* Zone (Klapper & Ziegler, 1982). The *Strophodonta iowensis* Zone correlates with Faunal Interval 28 (Upper *Tecnocyrtina* fauna) of Johnson & Trojan (1982).

Dutro (1981) listed *Hadrorhynchia*? *solon* (=*Ladogioides solon*) from the fauna of the West River and Ithica formations of New York, and is shown (ibid., fig. 7) to be restricted to the lower part of the *Warrenella laevis* Zone (ibid., fig. 2). The occurrence of *Ladogioides solon* in New York is correlated with the *Strophodonta iowensis* Zone. Johnson and Trojan (1982) correlated the upper *Tecnocyrtina* Fauna (F.I. 28) with the lower part of the *W. laevis* Zone of Dutro (1981).

The *Strophodonta iowensis* Zone is correlated with the middle and upper parts of the Calumet Member of the Waterways Formation of the Clearwater rivers area of northeastern Alberta. This is based on the occurrence of *Schizophoria lata*, *S.* cf. *S. athabaskensis*, and *Strophodonta* (*S.*) *albertensis* (Norris, 1983) in the Calumet Member (Day, 1988). The *Strophodonta iowensis* Zone of the the Lithograph City Formation correlates with *P. insita* bearing units in the Elk Point Basin of southwest Manitoba and Saskatchewan. In the Lake Winnipegosis-Lake Manitoba region the fauna of the "Micritic Limestone beds" of the Point Wilkens Member of the Souris River Formation includes: *Variatrypa* (*Radiatrypa*) *clarkei*, *I. independensis*, *Allanella allani*, *Cranaena iowensis*, *Athyris vittata*, and *Eleutherokomma* sp. (Norris, Uyeno & McCabe, 1982). In Saskatchewan, Unit B of the Davidson

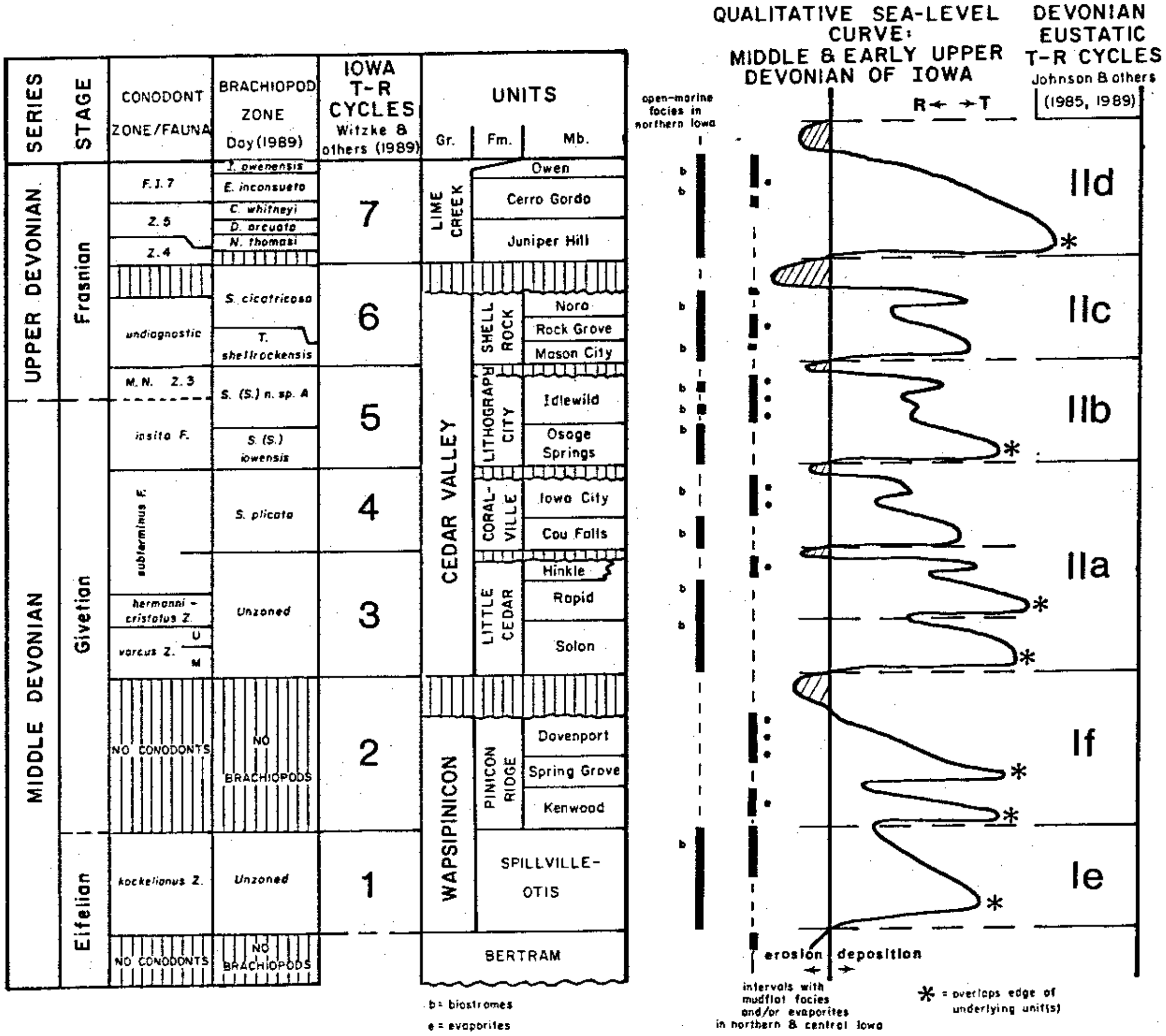

Figure 2. Stratigraphic and biostratigraphic framework for the Eifelian, Givetian, and Frasnian strata of the Iowa Basin showing relationships between the qualitative Devonian sea-level curve of Witzke et al. (1988) and the Devonian eustatic sea-level curve of Johnson et al. (1985). Conodont zones listed in the Lime Creek Formation are those described in Day (in press). Conodont faunas of the Wapsipinicon and Cedar Valley groups are summarized in Witzke & others (1988). Note that the upper conodont fauna in the Lithograph City Formation is correlated with Montagne Noire (M. N.) Zone 3 (Klapper, 1988) on reported occurrences of *Ancyrodella rugosa*, *A. africana*, and *A. alata* (late form) in Witzke et al. (1988, p. 243). Modified from fig. 10 of Witzke et al. (1988), fig. 2 of Day (1988), and fig. 12 of Johnson et al. (1985), after fig. 2 of Day, in press.

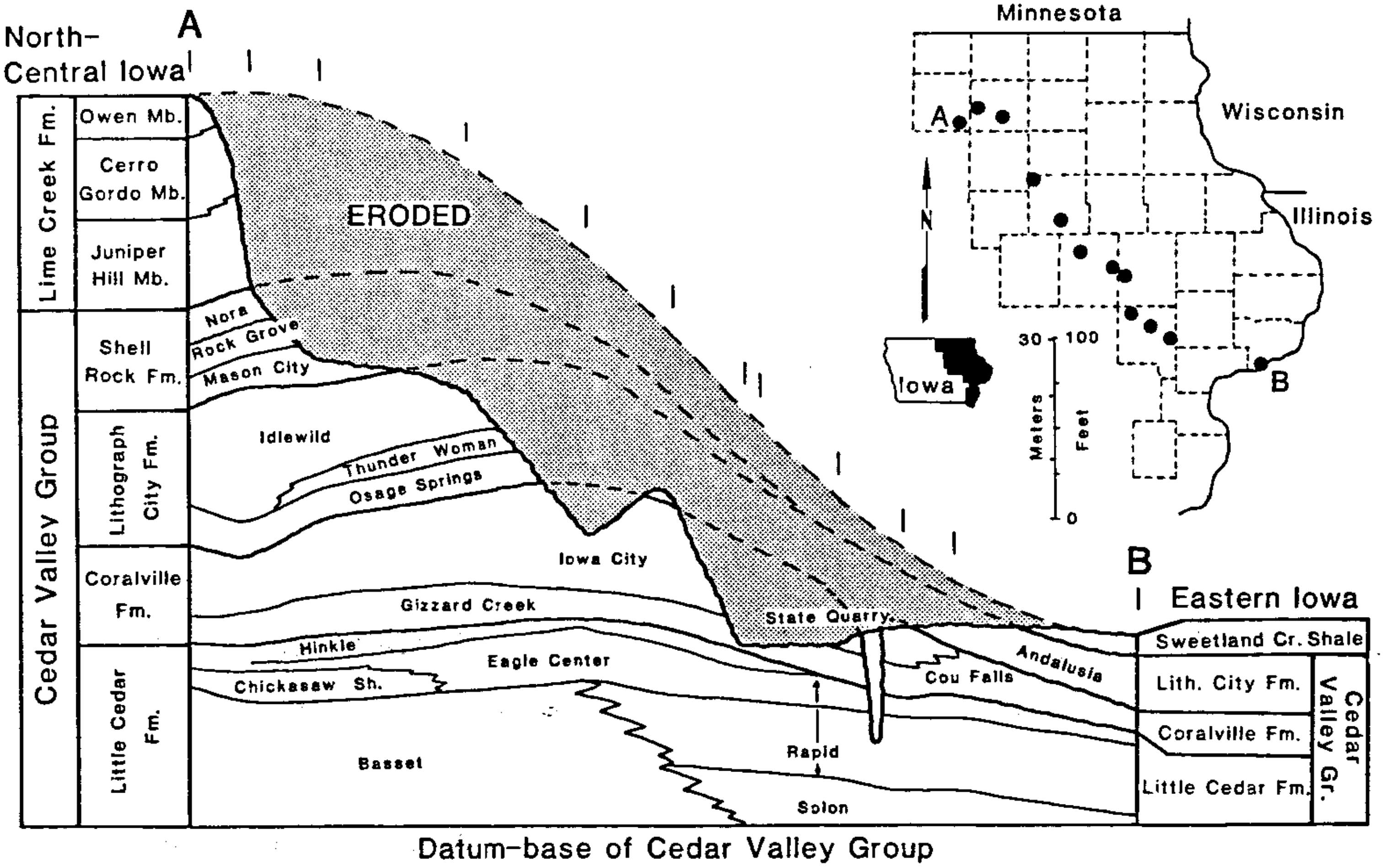

Figure 3. Generalized stratigraphic cross-section of the late Givetian-late Frasnian strata of north-central and eastern Iowa. Only the Frasnian portion of the Sweetland Creek Shale is included in the sequence shown in extreme eastern Iowa, (modified from fig. 1, Witzke et al., 1988; after fig. 1 of Day, 1988).

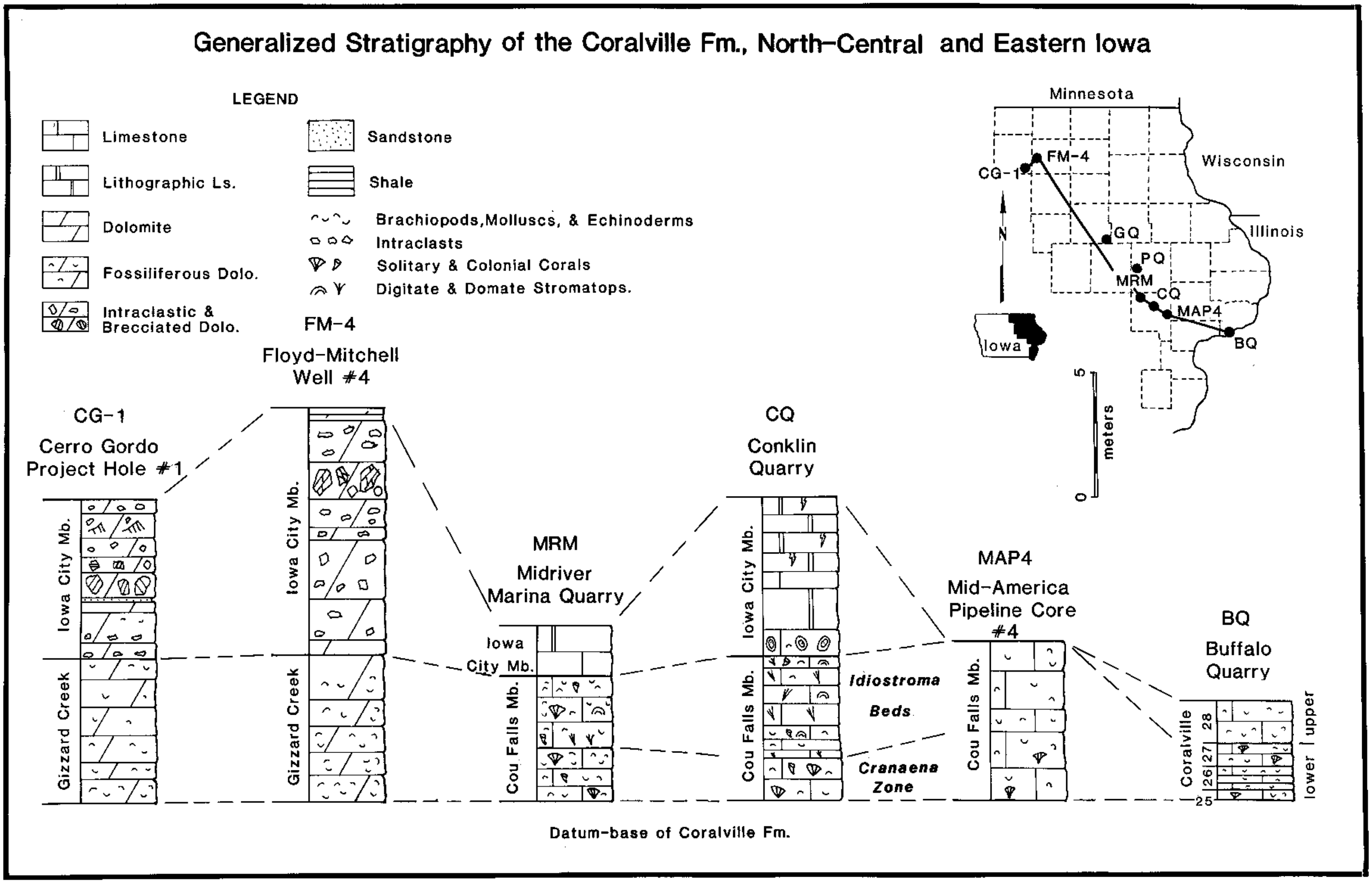

Figure 4. Generalized stratigraphy of the Coralville Formation in north-central and eastern Iowa. Locality GQ=Glory Quarry in southern Buchanan County, and PQ=Palo Quarry in Linn County. After fig. 3 of Day (1988).

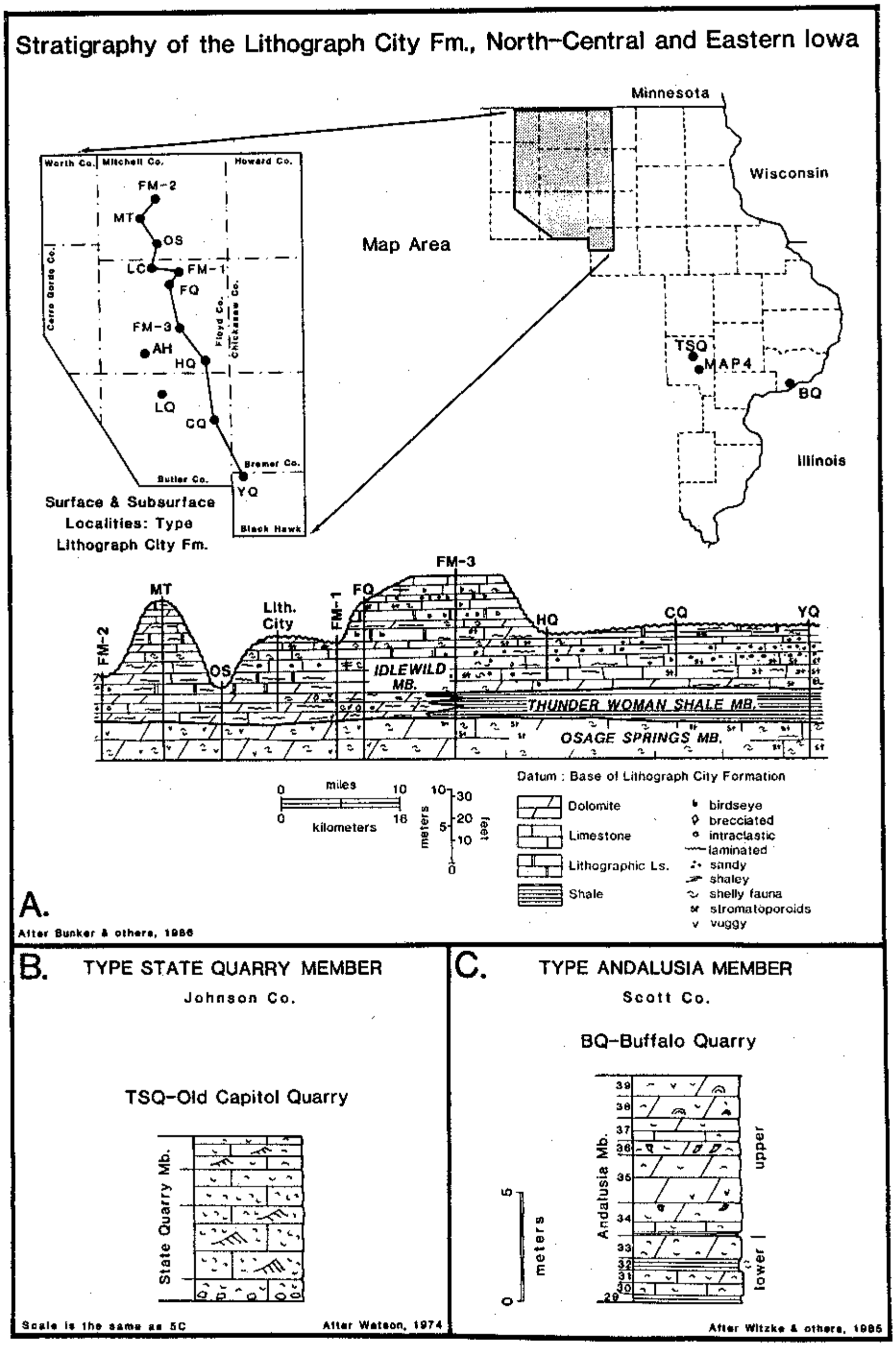

Figure 5. Stratigraphy of the Lithograph City Formation in north-central and eastern Iowa. **A.**--Stratigraphy of the type Lithograph City Formation in the type area in north-central Iowa, localities include: FM-2=Floyd-Mitchel Project Hole #2, MT=Mitchell, Iowa, OS=Osage Springs, LC=Lithograph City, FM-1=Floyd-Mitchell Project Hole # 1, FG=Floyd Quarry, FM-3= Floyd-Mitchell Project Hole # 3, HQ-Hanneman Quarry, CQ= Clarksville Quarry, YQ=Yokum Quarry, AH=Aureola Hills-Maxson Quarry. **B.**--Stratigraphy of the type State Quarry Member at the Old State Capitol Quarry on the west side of Coralville Lake in Johnson County (modified from fig. 17 of Watson, 1974). **C.**--Stratigraphy of the type Andalusia Member at the Buffalo Quarry=Davenport Cement Co. Quarry in Scott County in extreme eastern Iowa (modified after fig. 5 of Witzke & others, 1985; after fig. 5 of Day (1988).

Member of the Souris River Formation contains *V. (R.) clarkei*, *I. independensis*, *Allanella allani*, *Athyris vittata*, and *Schizophoria* sp. (Norris, Uyeno & McCabe, 1982).

Norris & Uyeno (1983) reported *Ladogioides pax*, *V. (R.) klukasi*, *Schizophoria lata*, *Tecnocyrtina billingsi*, and *Eleutherokomma impennis* from the Peace Point Member of the Waterways Formation in the Gypsum Cliffs area of northeastern Alberta. These were correlated with the Lower *asymmetricus* Zone (see Johnson & Norris, 1972, and Johnson & Trojan, 1982) and may correlate with part of the upper *S. iowensis* or lower part of the *Strophodonta* sp. A Zone of Iowa.

Norris and Uyeno (1981) reported brachiopod faunas correlated with the Lowermost and Lower *asymmetricus* zones from the Waterways Formation in the Birch River and Powell Creek area of the District of Mackenzie in northeastern Alberta. The *Strophodonta iowensis* Zone 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.*

Strophodonta sp. A Zone

The base of this zone is defined by the first occurrence of *Strophodonta* (*Strophodonta*) sp. A in the fauna of the upper Andalusia Member (unit 34, Witzke et al., 1985, fig. 5, p. 35) of the Lithograph City Formation at the Buffalo Quarry in Scott County Iowa. *Orthospirifer capax*, *Independatrypa independensis*, and *Cranaena* sp. also occur in this zone in the upper Andalusia Member at the Buffalo Quarry.

Strophodonta sp. A occurs in the Idlewild Member of the Lithograph City in north-central Iowa which allows a tentative correlation with the "upper" Andalusia Member. Witzke et al. (1985, 1988) reported the conodonts *Ancyrodella rugosa*, *A. africana*, and *A. alta* (late form) from high in the upper Andalusia Member at the Buffalo Quarry and allow direct correlation with Zone 3 of the Frasnian Montagne Noire conodont zonation of Klapper (1988). The *Strophodonta* (*S.*) sp. A Zone was correlated by Day (1988) with Faunal Interval 29 of the Great Basin Devonian (Johnson et al., 1980).

The occurrence of *Eleutherokomma jasperensis* in the upper Idlewild Member of the Lithograph City Formation in north-central Iowa allows correlation of the *Strophodonta* sp. A Zone is with Unit IV based on the reported (Norris & Uyeno, 1981) occurrence of *E. jasperensis* in the upper Calumet Member of the Waterways Formation in the Birch River and Powell Creek area of the District of Mackenzie in northeastern Alberta.

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OBSERVATIONS ON THE CATHODOLUMINESCENCE PETROGRAPHY OF THE CORALVILLE FORMATION NEAR IOWA CITY: IMPLICATIONS FOR REGIONAL DIAGENETIC PATTERNS IN THE DEVONIAN CEDAR VALLEY GROUP

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INTRODUCTION

Recently completed syntheses of stratigraphy and depositional history of the Eifelian-Frasnian (Middle-Late Devonian) carbonate rock sequences in Iowa (Bunker et al., 1983, 1986; Witzke et al., 1985, 1988) are responsible for stimulating a new group of studies of these rocks. Papers by Plocher and Ludvigson, Day, and Parse and Plumley in this guidebook are examples. The recognition of successive T-R depositional cycles, each separated by episodes of subaerial exposure (Fig. 1), have profound implications for interpreting the diagenetic environments in which rocks of the Cedar Valley Group were chemically stabilized. Specifically, exposure during regressions should have resulted in basinward migration of meteoric phreatic lenses, dispersing pore waters that are widely acknowledged to be aggressive diagenetic fluids in carbonate sediments. Further, each T-R cycle may have been largely stabilized by a distinct incursion of meteoric fluids, so that early diagenetic patterns in each formation of Witzke et al. (1988) could be related to a unique "meteoric event" (see Plocher and Ludvigson in this guidebook), rather than a single inclusive episode of diagenetic stabilization for the entire Cedar Valley Group.

Gross diagenetic lithofacies patterns described by Witzke et al. (1988) along the Iowa outcrop belt are in accord with this interpretation. Dolomitized open marine skeletal wackestones/ packstones in each cycle are overlain by restricted marine/nonmarine limestones in the "inner shelf" facies tract of north-central Iowa. These patterns suggest that: 1) processes responsible for dolomitization (meteoric-marine mixing zone?) were specific to each depositional cycle, and 2) chemical stabilization of the micrites in the fenestral limestones capping each cycle was concurrent with subaerial exposure, and thus made them resistant to dolomitizing processes that operated more effectively on the immediately overlying transgressive marine deposits.

While dolomite-limestone facies trends can be used to draw general conclusions regarding the diagenesis of Cedar Valley carbonates, differences in the behavior of environmental tracers (stable isotopes, trace elements) between calcite and dolomite complicate the application of geochemical studies in mixed lithologies. Cedar Valley rocks in the Iowa City area of Johnson County are almost completely preserved as limestones, and still contain the full complement of marine-nonmarine depositional facies that are missing to the southeast. Thus, the Iowa City area serves as an especially useful study area for petrographic and geochemical investigations of diagenesis in the Cedar Valley Group. Plocher and Ludvigson (this guidebook) contrast the diagenetic styles in the rocks spanning the Little Cedar-Coralville formational contact. This paper addresses the environments of diagenesis in the Coralville Formation (Fig. 1), and discusses features related to the contact with the overlying Lithograph City Formation.

CORALVILLE AND LITHOGRAPH CITY FORMATIONS

The Coralville Formation locally consists of the Cou Falls Member, primarily an open marine skeletal packestone, overlain by the Iowa City Member, a generally shallowing upward succession passing from restricted marine units into supratidal fenestral lime mudstones. One of the noteworthy diagenetic features of the upper part of the Iowa City Member is the presence of isopachous bladed carbonate cements in

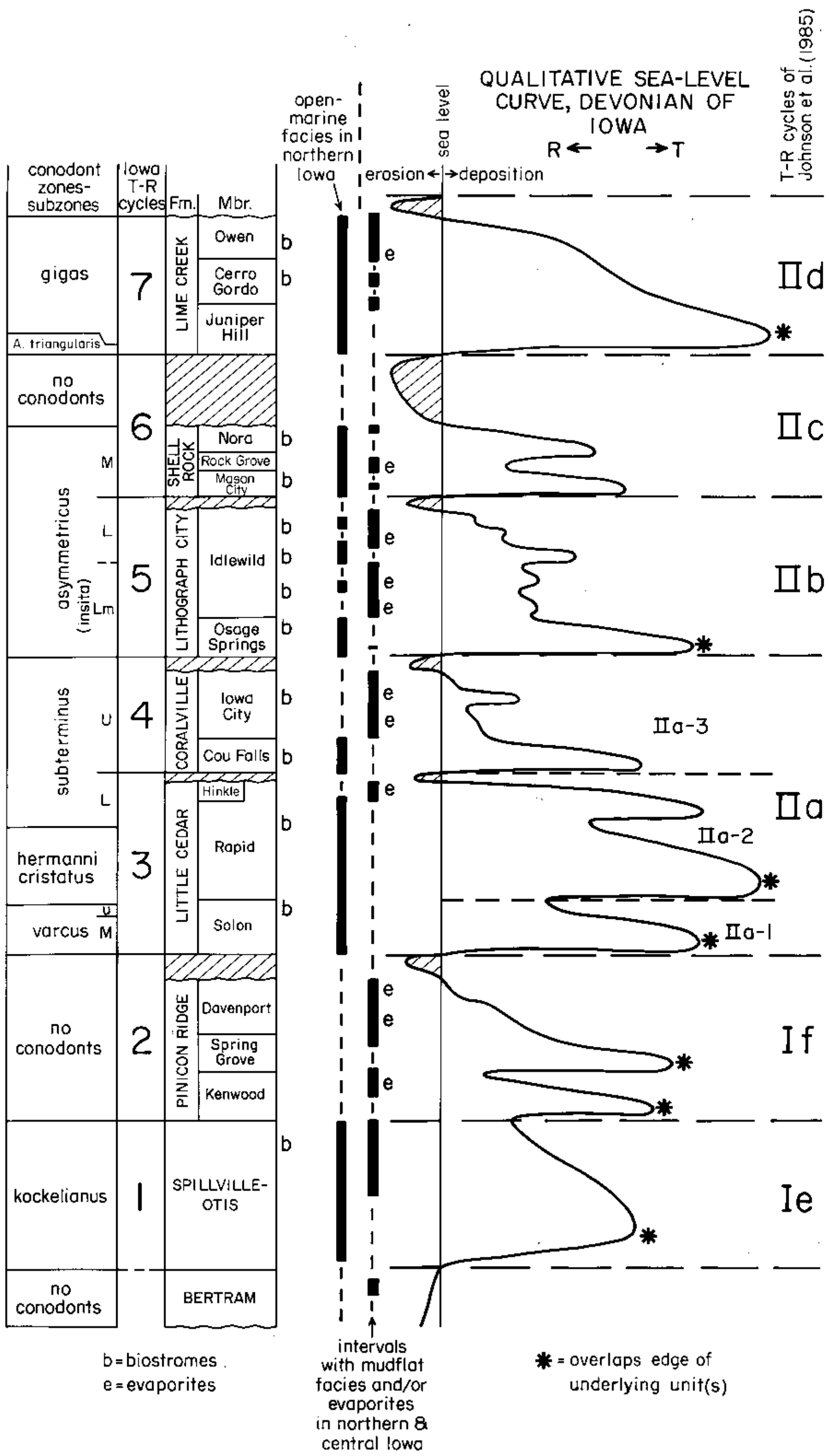

Figure 1. Qualitative sea-lelvel curve for late Middle and early Upper Devonian rocks in Iowa, and relationships to the T-R cycles of Johnson et al. (1985). From Witzke et al. (1988).

stromatactis and microkarstic voids ("drusy calcite" calcite" of Kettenbrink, 1973, p. 111; "bladed calcite" of Witzke, 1984, p.28). These cements will be discussed further in this paper.

The Lithograph City Formation locally includes the State Quarry and Andalusia members. The State Quarry consists largely of cross-bedded skeletal and pelletal calcarenites, and is confined to a narrow channel-filling sequence exposed along Coralville Lake (Watson, 1974; see Bunker and Witzke in this guidebook). Watson (1974, p. 66) noted that pelletal calcarenites of the State Quarry can be found along a "burrowed" unconformable contact with fenestral lime mudstones from the upper Iowa City Member of the Coralville. This contact will also be the focus of further discussion in this paper.

The depositional and erosional paleotopography developed on the top of the Coralville Formation are important aspects in the synthesis of the depositional/diagenetic history of the Lithograph City Formation and immediately underlying units. Accelerated rates of carbonate production in shallow depositional realms led to the progradation of supratidal "inner shelf" facies to the "inner-shelf margin" of the Coralville Formation in the Iowa City area. During the subsequent marine offlap that preceded deposition of the Lithograph City Formation, the platform edge of the "inner-shelf margin" was incised by subaerial erosion, creating the channel system that was later infilled by the State Quarry Member. The topographic relief implied by this facies architecture has important implications for the diagenesis of the units spanning this interval.

CATHODOLUMINESCENCE PETROGRAPHY

Cathodoluminescence (CL) refers to the visible light spectrum emitted by materials under bombardment by an electron beam. CL petrography examines the microscopic fabrics of light emitted from polished surfaces of rock specimens as a tool for evaluating microscopic chemical heterogeneity. While the technique was pioneered in the 1960's (Sippel and Glover, 1965), it now is considered to be a routine technique in diagenetic studies of carbonate rocks.

The principal utility of CL petrography in studies of carbonate diagenesis is in developing strategies for microsampling rock fabrics by interpreting spatial and temporal aspects of chemical heterogeneity. The trace elemental controls on CL in carbonates are discussed at length in Machel (1985). While there are uncertainties regarding the elemental characteristics that activate specific CL wavelengths and intensities, the research experience of the author and many other carbonate petrologists has been that manganese substitution in the carbonate lattice exerts the principal control on CL behavior. Mason (1987) reported that Mn concentrations as low as 10 ppm can activate CL in calcite, and that while Fe is regarded as a quenching element, it does not reliably extinguish CL response.

The principal environmental controls on microscopic CL fabrics in carbonates involve redox reactions that govern the mobility of divalent transition metals, specifically the stability of Mn^{2+} and Fe^{2+} in pore fluids. The reduced aqueous species of both elements are preferentially substituted in the calcite lattice relative to Ca (Veizer, 1983), and CL responds sensitively to changes in redox environments. Measurements of trace elemental concentrations are needed to develop a fully satisfactory understanding of CL phenonomena in carbonate rocks. Nevertheless, CL photomicrographs can be and are used to formulate tentative hypotheses about the diagenetic environments in which rocks and their constituents were stabilized. This paper advances several geochemical and environmental speculations on diagenesis in Cedar Valley carbonates that are based on interpretations of CL photomicrographs, using a few guiding principles.

Possible Meaning of Luminescence

The most important requirement for the formation of luminescent calcites is the establishment of reducing conditions in which Mn^{2+} is stable in solution. Mn and Fe sources in marine carbonates are derived from detrital components that are introduced as particulate oxides and oxides adsorbed on detrital clays. In marine carbonate sediments, sufficient Mn quantities generally are present to assure CL activation provided that reducing environments are established during the precipitation of

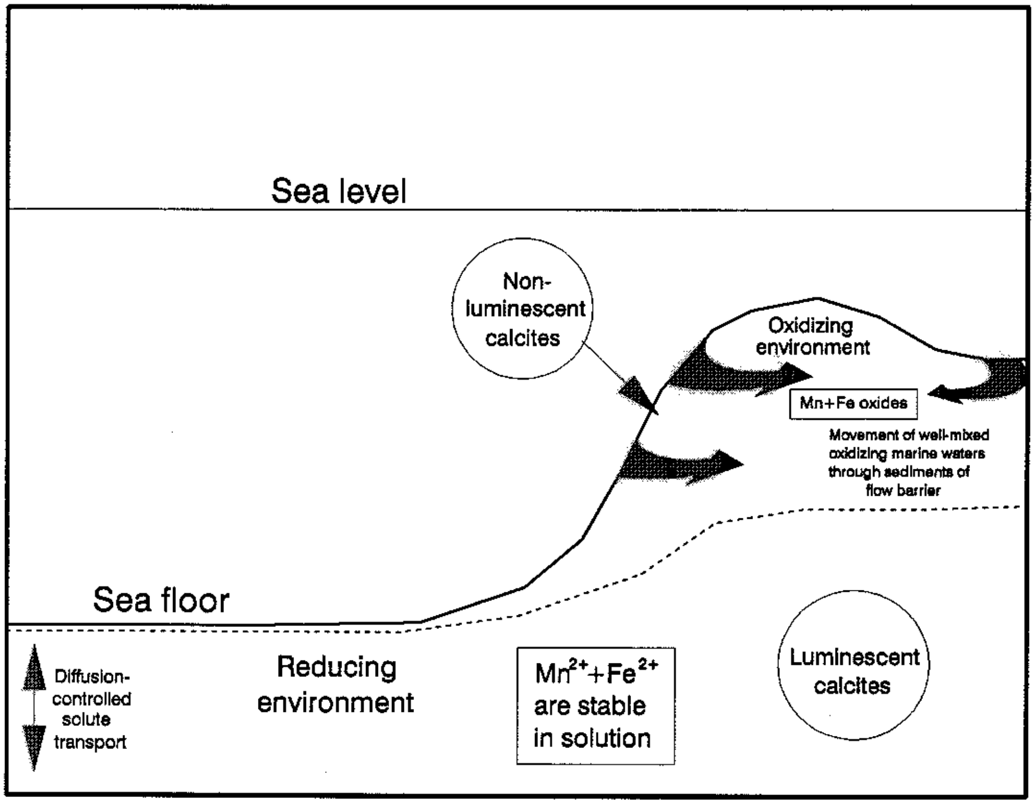

Figure 2. Diagram showing idealized zonation of marine phreatic diagenetic environments, with characteristic CL signatures.

diagenetic calcites. Consequently, the timing of different generations of calcite precipitation, and coordination with migrations of redox fronts will determine the heterogeneous CL signatures that frequently are recorded in ancient carbonate rocks.

Possible Meaning of Nonluminescence

Unless other data indicate otherwise, nonluminescent calcite suggests precipitation in oxidizing environments. As suggested by Czerniakowski et al. (1984, p. 868), nonluminescence in marine carbonates may indicate: 1) original calcite precipitated from oxidizing marine waters, or 2) diagenetic calcites with very low concentrations of Mn, or very high concentrations of Fe. Recent data suggests, however, that Mn concentrations can be safely presumed to control luminescence in calcite (Mason, 1987).

Paradigm for Marine Phreatic Diagenesis

The simplest interpretation for the diagenesis of a shallow marine carbonate mud is that sediments were stabilized to diagenetic calcites in marine phreatic environments just below the sediment-water interface (Fig. 2). Submarine lithification has been demonstrated in modern carbonate environments (James et al., 1976; Schlager and James, 1978). Even on well-oxygenated sea floors, reducing environments may be quickly established below the sediment-water interface as dissolved oxygen is exhausted by aerobic microbes, establishing a succession of decreasingly energetic anaerobic microbial environments, including nitrate-reducing, sulfate-reducing, and methanogenic zones (Martens and Berner, 1974; Froelich et al., 1979; Berner, 1981). In these settings, Mn^{2+} released into solution from the reduction of detrital oxides would be incorporated in newly-forming diagenetic calcites in reducing environments, while original

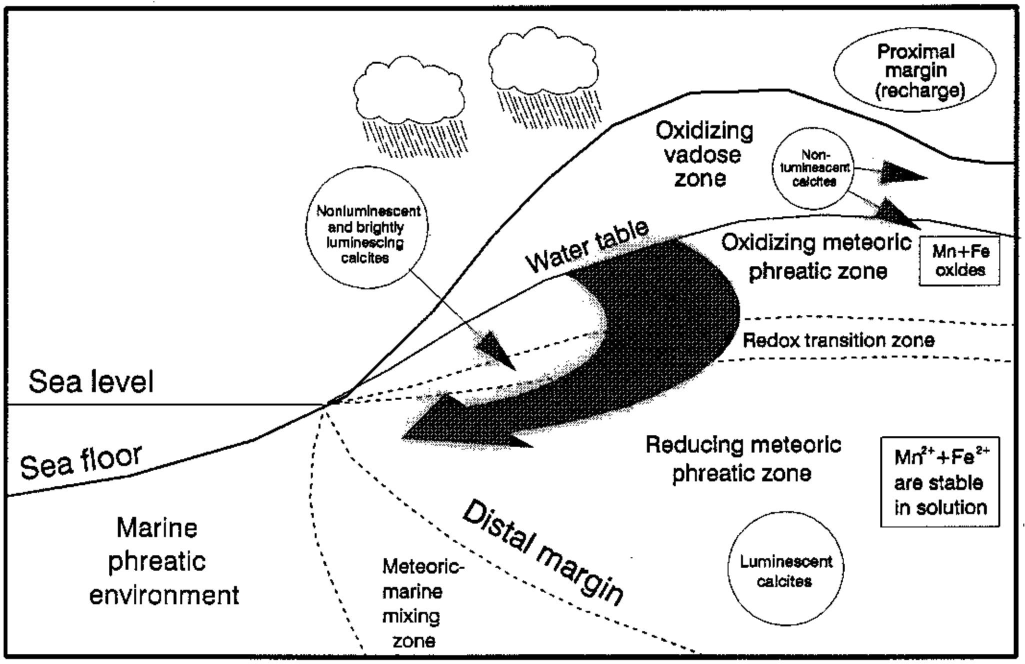

Figure 3. Diagram showing idealized zonation of meteoric diagenetic environments, with characteristic CL signatures.

components with stable low-magnesium calcite (LMC) mineralogy might be little-affected by evolving pore fluid chemistry. Mud-rich rocks that stabilized in this setting would be expected to have luminescent Mn-bearing micrites and skeletal grains with originally unstable mineralogy (ie: high-magnesium calcite (HMC) echinoderms), while those with originally stable mineralogy (ie: LMC brachiopod valves) remain nonluminescent, reflecting their original formation in oxidizing environments (see Czerniakowski et al., 1984, p. 868).

In paleotopographic settings where marine currents induced active circulation of seawater through the sediment column (ie. reefs), nonluminescent bladed marine spars could have been precipitated by well-mixed oxidizing pore fluids (Fig. 2). While these fabric constituents are unstable components, integrated CL petrographic and geochemical studies of ancient shallow marine cements shows that original chemistry may in part be retained in relict nonluminescent portions of altered cements (Carpenter and Lohmann, 1989).

Paradigm for Meteoric Diagenesis

Another possible interpretation for the diagenesis of shallow marine carbonates in epeiric seas is that sediments were stabilized by meteoric pore fluids during eustatic marine regression. This setting has been suggested for many ancient cratonic carbonates, and isotopic data from micrites in the skeletal packstones of the Cou Falls Member of the Coralville Formation suggest that they were stabilized by meteoric waters (see Plocher and Ludvigson, this guidebook). The downflow succession of redox environments in meteoric groundwater flow systems have been discussed by Champs et al. (1979), and applications to the CL signatures of meteoric diagenesis have been discussed by Ludvigson (1988).

Because of active exchange with atmospheric gases, meteoric vadose zones are mainly oxidizing environments, although localized reducing environments may be established (Fig. 3). The upper (proximal) portions of meteoric phreatic groundwater environments also are oxidizing, although the system is closed with respect to new inputs of dissolved oxygen. The down-flow limits of the zone of oxidizing phreatic groundwaters are determined by rates of groundwater recharge (flow), and the rate that dissolved oxygen is consumed by the oxidation of resident organic matter.

One of the important characteristics of meteoric phreatic environments is the fluctuation of redox boundaries because of the dynamic response of groundwater flow systems to short-term climatic perturbations. This environmental instability can result in rapid changes in the solubility of Mn, and typically leads to heterogeneous CL signatures. Proximal meteoric phreatic calcites are characterized by alternating nonluminescent and luminescent growth zones (Ludvigson, 1988; Barnaby and Rimstidt, 1989). Conversely, micrites stabilized in proximal meteoric settings may have heterogeneous CL intensities ranging from bright luminescence to nonluminescence, the latter indicating stabilization in oxidizing environments (Fig. 3).

Distal meteoric phreatic settings typically are anoxic, reducing environments, although Mn concentrations still may fluctuate in response to upflow migrations of redox fronts (the "manganese cycling effect" of Ludvigson, 1988). Consequently, calcites precipitated in distal meteoric phreatic environments characteristically are luminescent. Spars still may show zonations in the intensity of luminescence, however. While uniformly luminescent micrite fabrics imply stabilization in reducing environments, discriminations between marine phreatic and distal meteoric phreatic settings are dependent on isotopic and trace elemental signatures.

Application to Rocks of the Cedar Valley Group

Packstones of the Cou Falls Member, Coralville Formation

Figure 4 compares the CL and transmitted light petrography of skeletal-rich packstones in the Cou Falls Member, near the base of the Coralville Formation. Micritic matrix and echinoderm grains are brighly luminescent, while the skeletal calcites of brachiopods are nonluminescent. Isotopic data from this unit shows that brachiopods largely retain the composition of Givetian (Middle Devonian) marine carbonate, while the micrites, echinoderms, and cements are all signicantly depleted from marine carbonate values (see Plocher and Ludvigson, this guidebook). These observations indicate that the nonluminescent brachiopods represent the only original marine components left in the rock, and that all other calcites are of diagenetic origin. The CL signatures of the packstone are characteristic of stabilization in reducing marine-phreatic or distal meteoric-phreatic environments.

Fenestral Lime Mudstones of the Iowa City Member, Coralville Formation

Figure 5 compares the CL and tranmitted light micrographs of spar-filled fenestral voids and their surrounding micritic matrix. Spar fills in the fenestral voids consist of early cloudy, finely crystalline rims that grade into clear, coarser equant spars (Fig. 5a). The clear equant spars have a prominent CL zonation of nonluminescent-luminescent growths that record changes in pore fluid chemistry during the constructive growth of the cement crystals into the interior of the void. The earlier nonluminescent zone suggests that initially oxidizing environments were superceded by reducing environments. Conversely, the early cloudy spars have a speckled CL signature that is not related to constructive crystal growth. At higher magnification (Fig. 6), the speckled signature consists of small domains of brightly luminescent and nonluminscent calcite, suggesting that the cloudy rim cements are altered from an unstable precursor (nonluminescent?) cement.

Micrites enclosing the fenestral spar-fills include both luminescent and nonluminescent domains, suggesting that portions were stabilized in reducing and oxidizing environments. This signature markedly contrasts with the uniformly luminescent micrite in the Cou Falls Member (Fig. 4).

The general environmental interpretations attributed to "birdseye limestones" and the CL petrography of the fenestral calcilutites (Figs. 5, 6) indicate that these rocks were largely stabilized in oxidizing environments, with later diagenesis in reducing environments. Transitions from marine (?) vadose to meteoric vadose deposition/ diagenesis of the muds may be suggested, with later diagenetic alterations in proximal to distal meteoric-phreatic environments.

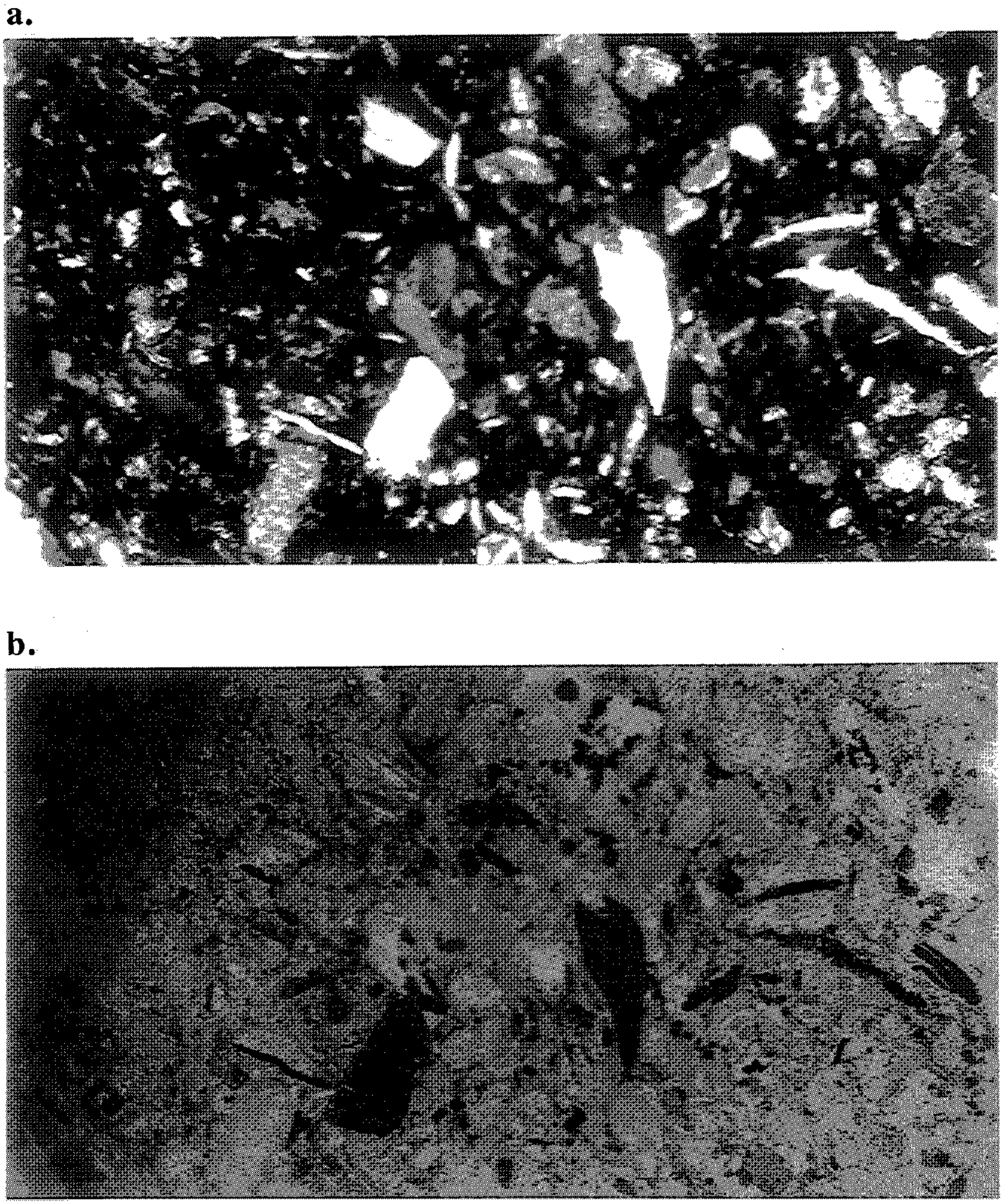

Figure 4. Matching photomicrographs of skeletal packstones from the Cou Falls Mbr of the Coralville Fm. Sample PC-79 from the Plum Creek Core, 4.2 mm FOV. a. Transmitted light. b. Cathodoluminescent light.

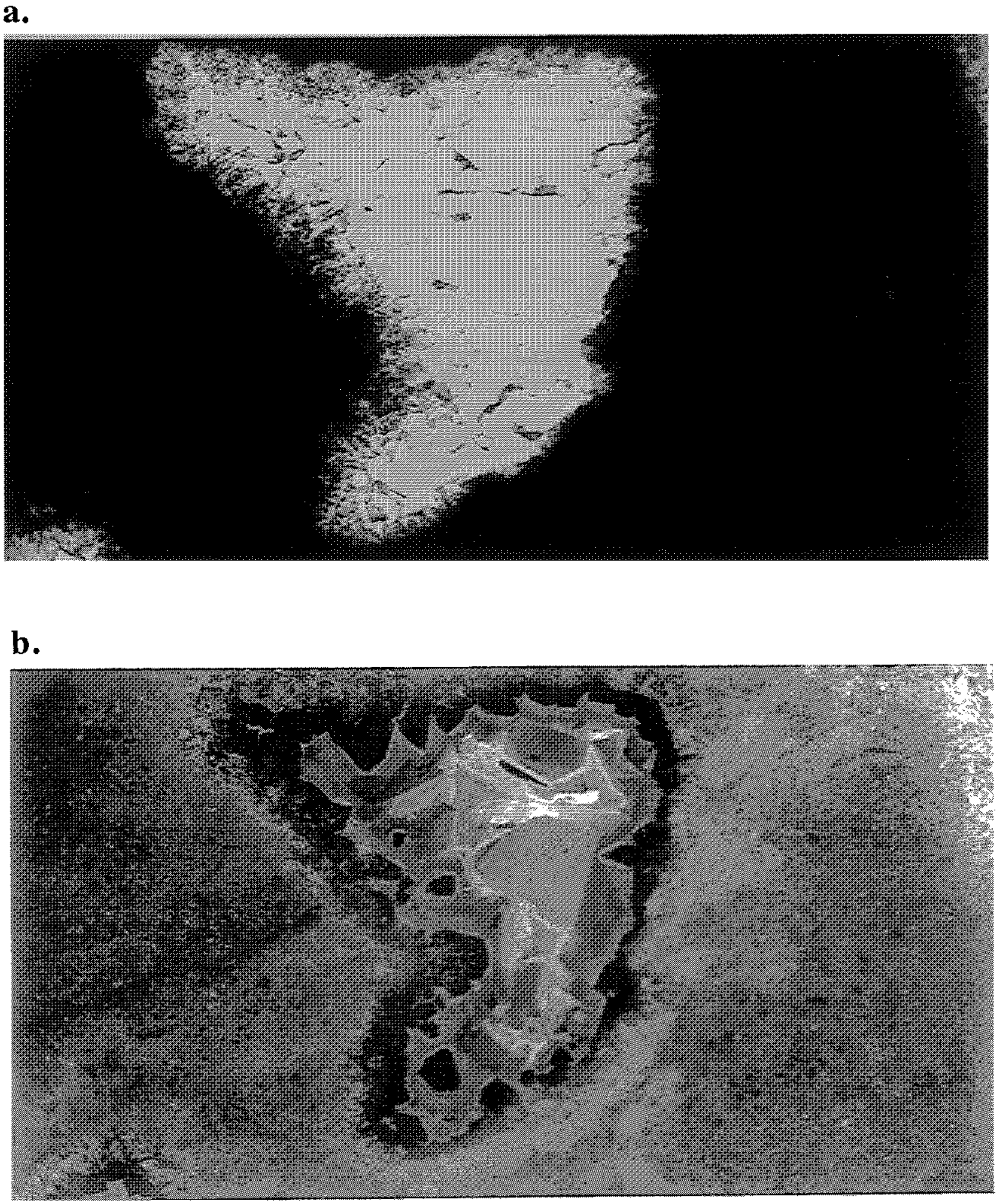

Figure 5. Matching photomicrographs of spar-filled "birdseye" in fenestral lime mudstone from the Iowa City Mbr of the Coralville Fm. Sample UCOR-CONK, 4.2 mm FOV. a. Transmitted light. b. Cathodoluminescent light.

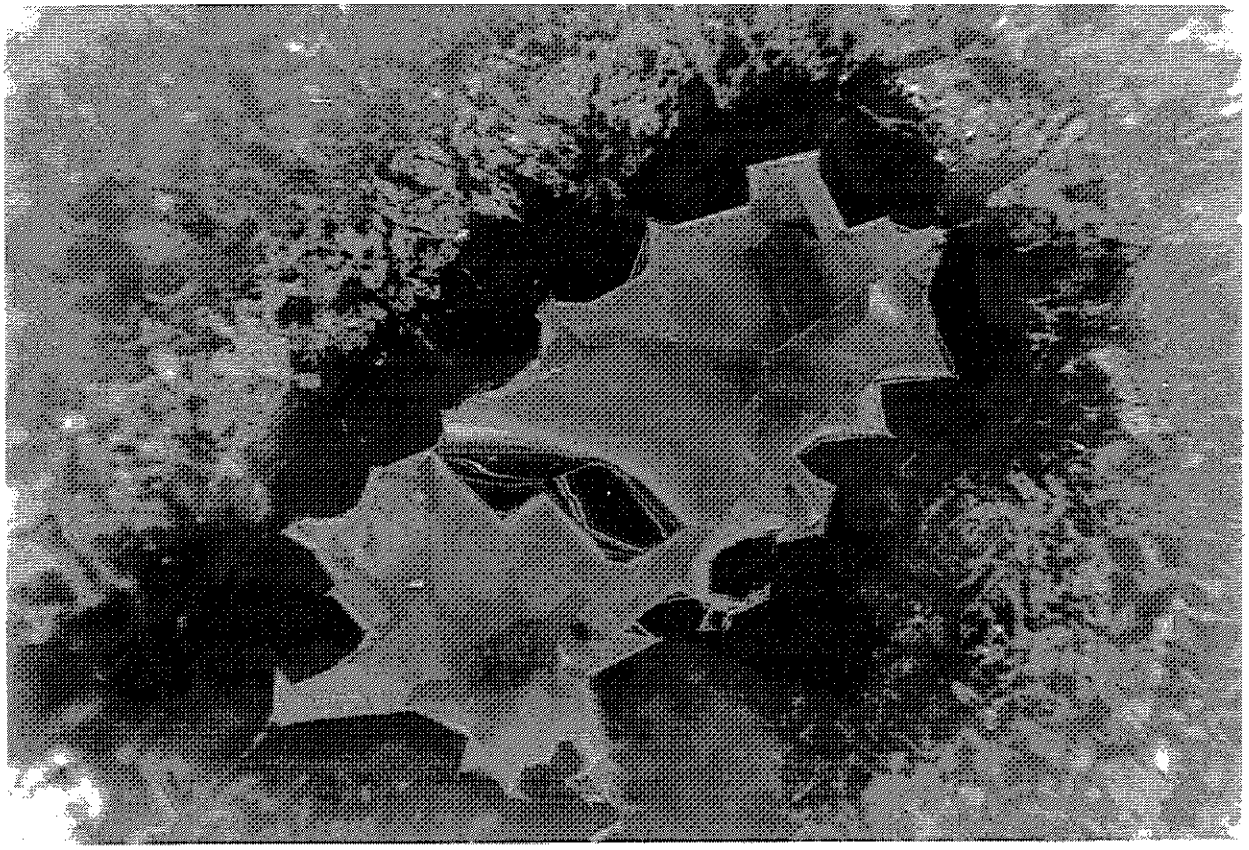

Figure 6. High magnification cathodoluminescence photomicrograph of spar-filled "birdseye" in fenestral lime mudstone from the Iowa City Mbr of the Coralville Fm. Sample UCOR-CONK, 1.2 mm FOV.

Isopachous Bladed Cements in the Iowa City Member, Coralville Formation

Figure 7 compares CL and transmitted light micrographs of the isopachous bladed cements and the substrate of fenestal calcilutite on which they were precipitated. The bladed spars, elongate perpendicular to the substrate, consist of both clear and cloudy domains (Fig. 7a). Figure 7b shows that the clear areas are nonluminescent, whereas the cloudy areas are luminescent. Futhermore, close inspection reveals that both nonluminescent/clear domains and luminescent/cloudy domains occur along the same growth bands in the spar. Therefore, the CL patterns do not result from primary crystal zonation, but result from alteration of an unstable precursor. At higher magnification (Fig. 8), the cloudy/luminescent domains have highly irregular shapes, and their presence along intercrystalline boundaries between nonluminescent calcites suggests that the luminescent calcites are alteration products within originally nonluminescent bladed spars. The gross morphology of these cements suggests that they may be relict shallow marine cements (see Longman, 1980) that were altered by reducing diagenetic fluids.

The optical and CL petrography of the partially altered, originally nonluminescent isopachous bladed cements very closely resembles that of Frasnian (Late Devonian) radiaxial calcite marine cements from Alberta recently described by Carpenter and Lohmann (1989). The same term can be applied to the bladed spars under consideration in this report. Carpenter and Lohmann (1989) reported that the nonluminescent portions of the radiaxial calcites retain the primary geochemical signatures of Frasnian marine carbonate, thus providing information on the chemistry of ancient oceans.

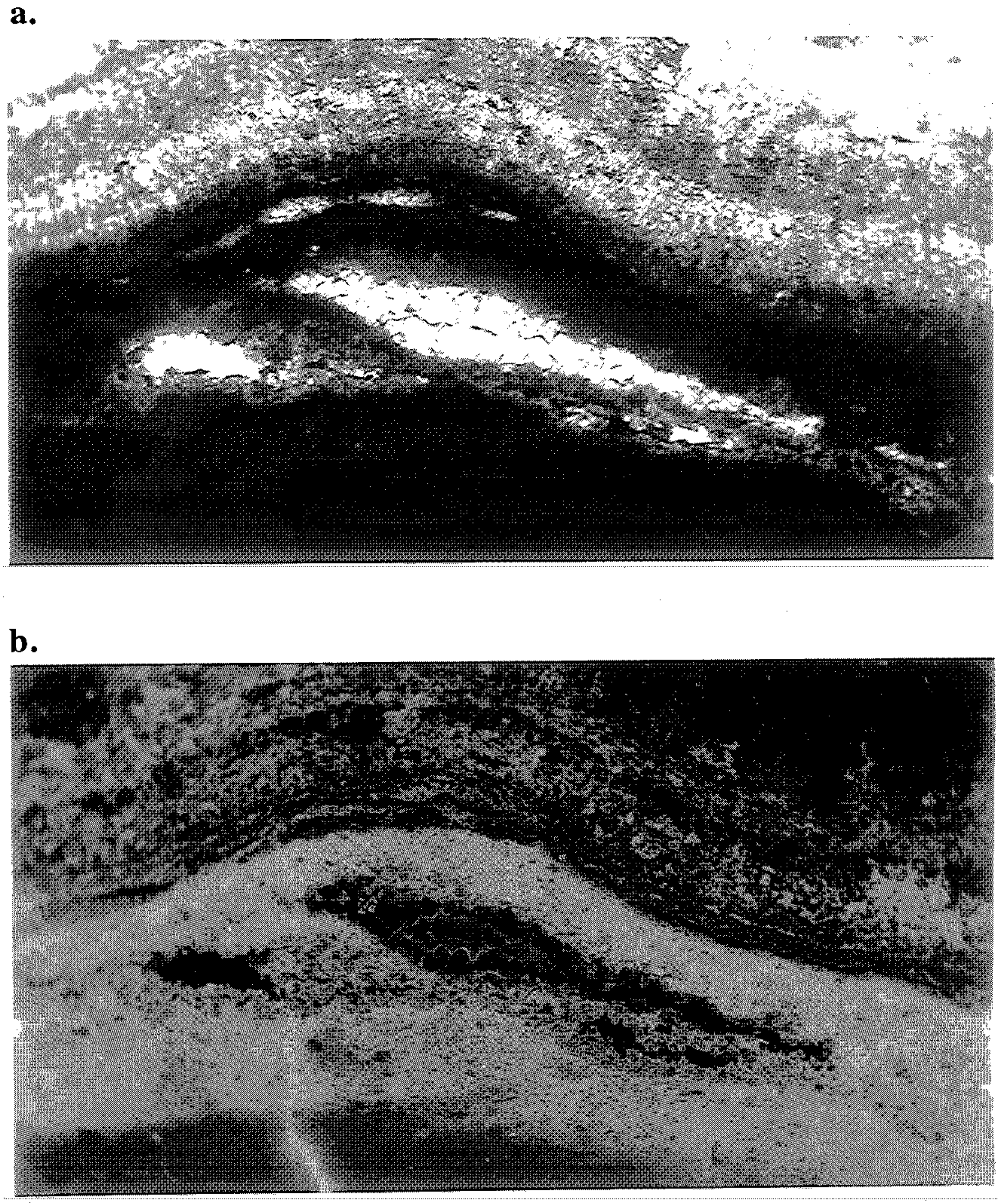

Figure 7. Matching photomicrographs of isopachous bladed calcite cement grown on fenestral lime mudstone from the Iowa City Mbr of the Coralville Fm. Sample UCOR-CONK, 4.2 mm FOV. a. Transmitted light. b. Cathodoluminescent light.

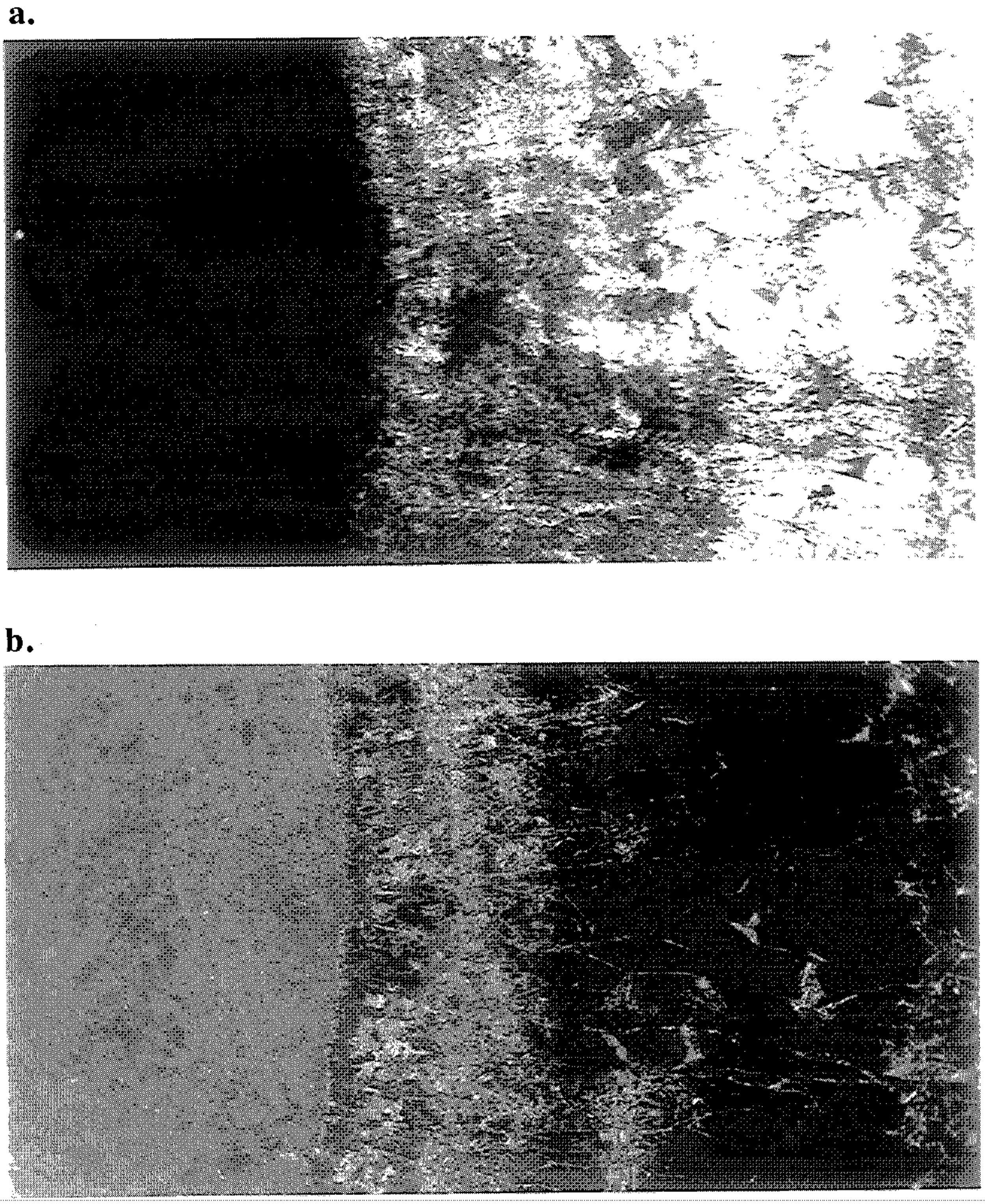

Figure 8. Matching photomicrographs of isopachous bladed calcite cement from the Iowa City Mbr of the Coralville Fm. Sample UCOR-CONK, 4.2 mm FOV. a. Transmitted light. b. Cathodoluminescent light.

Similar studies of the radiaxial calcites from the Coralville Formation are warranted.

The brightly luminescent micrites bordering the bladed spars pass into dully to nonluminescent micrites at the bottom of Figure 7. This suggests that the luminescent area, which engulfed a spar-filled fenestral void (compare to Figs. 5 and 6), is an alteration rim to the larger void filled by the bladed spar. This suggests that the large void was either dissolved by reducing pore fluids, or that the creation of the void was accompanied by the development of microporosity in the surrounding micrites, with later filling/alteration, possibly by the same generation of luminescent calcites that form the altered domains in the bladed spar.

Details of the Contact Between the Coralville and Lithograph City Formations

Figure 9 compares CL and transmitted light micrographs of the microkarstic contact between older fenestral lime muds of the Iowa City Member of the Coralville Formation, and younger pelleted calcarenites of the basal State Quarry Member of the Lithograph City Formation. The former are nonluminescent whereas the latter includes dully luminescent micrites and small areas of brightly luminescent spars. A sheltered void fill within the Lithograph City Formation in the upper center of Figure 9 shows an area of micrite rimmed by isopachous bladed spar, both of which are nonluminescent. The boundary between the two CL domains suggests that the nonluminescent areas where stabilized earlier, and subsequently were partially altered during stabilization of the luminescent areas.

The relationships described above suggest the following: 1) as outlined earlier, fenestral limestones of the Iowa City Member were largely stabilized in oxidizing meteoric groundwaters; 2) pelleted calcarenites of the basal State Quarry Member were stabilized in reducing marine-phreatic or distal meteoric-phreatic environments; and 3) nonluminescent isopachous bladed spars and micrites record deposition of basal Lithograph City sediments by well-mixed, oxidizing marine waters, a record largely obscured by later diagenesis in reducing phreatic environments.

There are other important features associated with the microkarstic voids along the Coralville-Lithograph City contact. Figure 10 compares CL and transmitted light micrographs of a large spar-filled void within the Coralville Formation. Orange-colored columnar palisade cements with abundant ferric oxide inclusions concentrated along growth laminae are grown on an irregular pitted surface eroded into the enclosing micrites in the upper left-hand corner of Figure 10a. Figure 10b shows that the columnar palisade cements are nonluminescent, except for an area of speckled luminescence along the late thick darkly-colored lamina that borders a yet later generation of clear blocky equant spar (Fig 10a). The equant blocky spar shows a conspicuous CL zonation recording constructive crystal growth into the interior of the void. An early zone of nonluminescent clear spar is followed by alternations between brightly luminescent and nonluminescent zones, in turn followed by a zonation characterized by variable intensities of luminescence.

The void-filling cements shown in Figure 10 are interpreted to record in temporal sequence: 1) the deposition of speleothems in an oxidizing vadose environment (nonluminescent columnar palisade cements with ferric oxide inclusions), and 2) deposition of meteoric-phreatic calcites (clear blocky calcites), at first in an oxidizing phreatic environment (nonluminescent), and later in a reducing environment (luminescent). The void-filling sequence is consistent with a transition that would be expected during the upward movement of a meteoric phreatic water table, traversing from vadose, to shallow phreatic, to deeper phreatic environments. The late, darkly-colored speleothem lamina with speckled luminescence (Fig. 10) is interpreted as a growth phase that originally precipitated as a metastable carbonate (see Gonzalez and Lohmann, 1988), and was subsequently altered in a reducing phreatic environment.

Finally, fabric relationships shown in Figure 11 are pertinent to the paragenetic relationships between the various calcite generations under consideration. Figure 11 compares CL and transmitted light micrographs of another sediment and spar-filled microkarstic void along the Coralville-Lithograph City contact. Pelleted calcarenites of the Lithograph City to the lower left in Figure 11 are dully to brightly luminescent, whereas fenestral lime mudstones of the Coralville to the upper right in Figure 11 are nonluminescent to dully luminescent. A

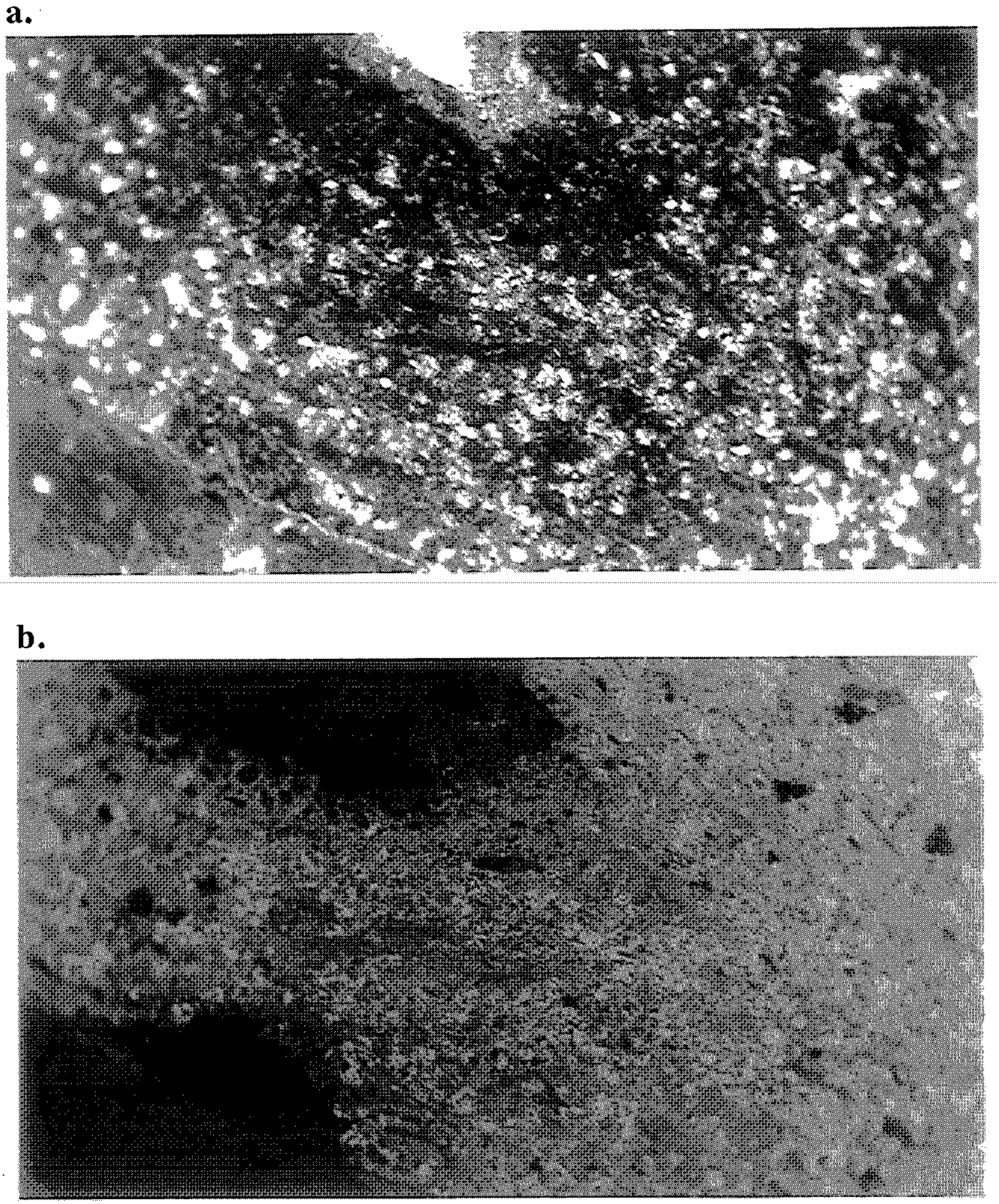

Figure 9. Matching photomicrographs of the contact between the Coralville and Lithograph City formations. Sample NL-B-S1, 4.2 mm FOV. a. Transmitted light. b. Cathodoluminescent light.

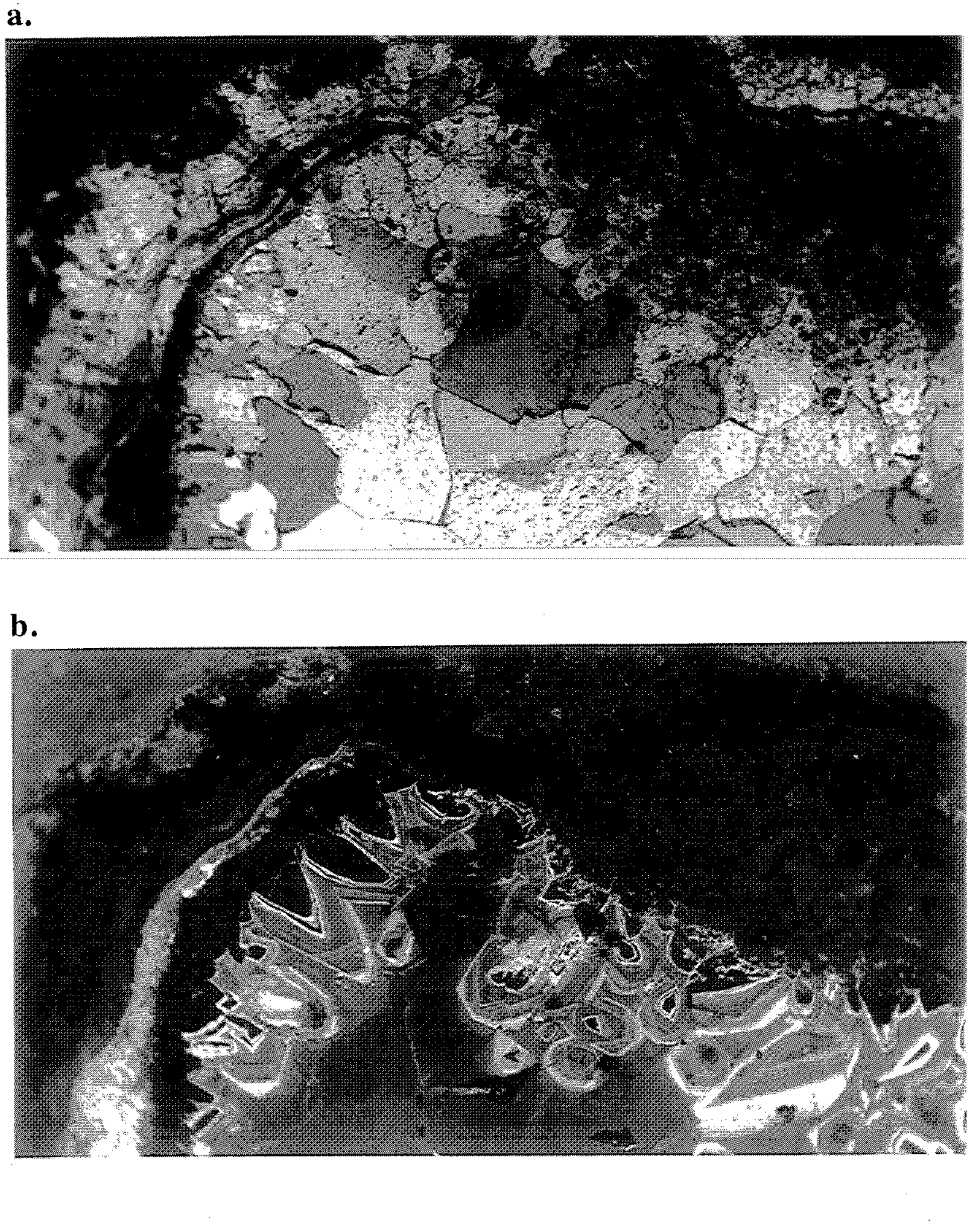

Figure 10. Matching photomicrographs of spar-filled microkarstic void at the contact between the Coralville and Lithograph City formations. Sample NL-B-S1, 4.2 mm FOV. a. Transmitted light. b. Cathodoluminescent light.

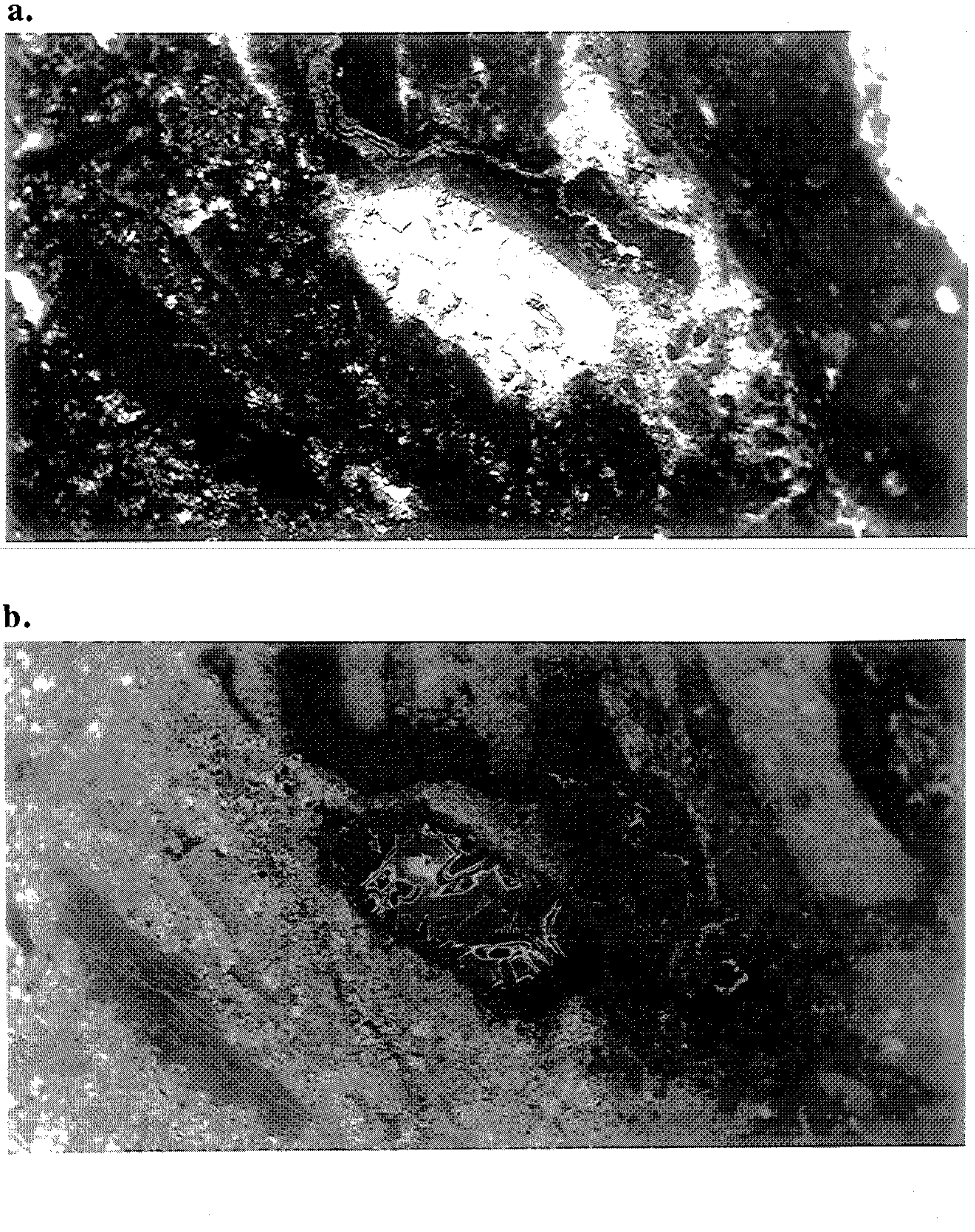

Figure 11. Matching photomicrographs of the contact between the Coravlille and Lithograph City formations, showing lithoclasts of upper Coralville fabrics enclosed in pelletal calcarenites of the Lithograph City. Sample NL-B-S1, 4.2 mm FOV. a. Transmitted light. b. Cathodoluminescent light.

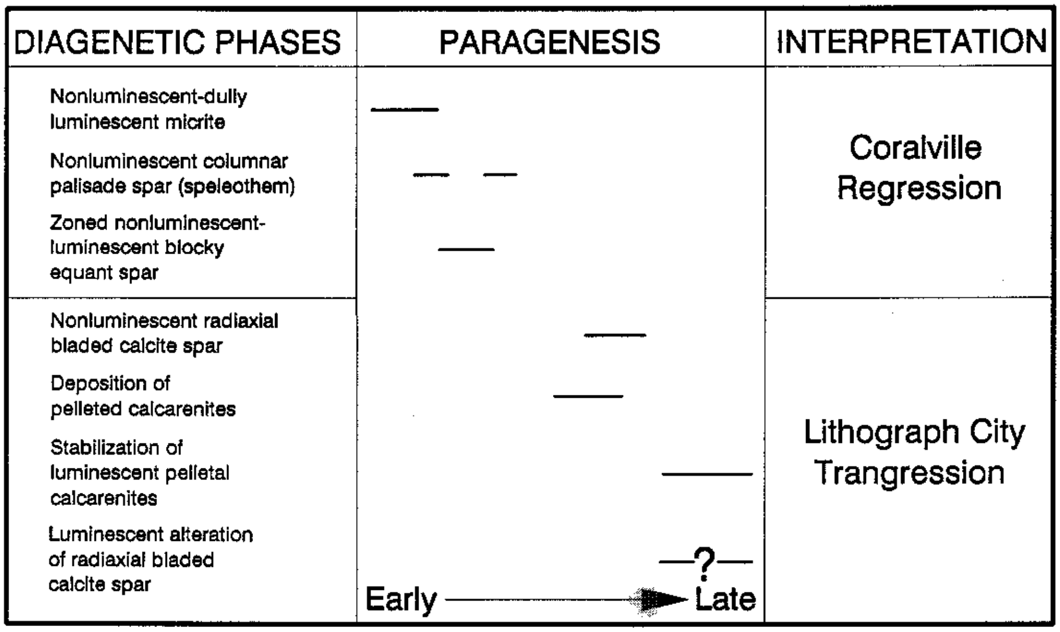

Figure 12. Tentative interpretations of the paragenesis of diagenetic phases in the Coralville and Lithograph City formations in the Iowa city area.

nonluminescent band along the irregular contact between the two major domains includes micrites, clear blocky spars, and a thin band of darkly-colored, columnar palisade cements with concentrations of ferric oxide inclusions along growth laminae.

Enclosed within the dully to brightly luminescent sediments of the Lithograph City Formation are two lithoclasts. The first, to the lower left in Figure 11, is an elongate fragment of nonluminescent micrite. The second, to the right of the micrite fragment, is an ovoid-shaped fragment of clear, blocky spar with conspicuous CL zonation. The two lithoclasts have CL signatures that are characteristic of fenestral fabrics in the Iowa City Member of the Coralville Formation (compare to Figure 5), and establish temporal relationships between these features and the later luminescent pelletal calcarenites of the State Quarry Member of the Lithograph City Formation. The darkly-colored palisade cement (speleothem calcite?) lines the void, and thus also predates the pelletal calcarenites of the Lithograph City, but evidently post-dates the erosion of the lithoclasts from the fenestral limestones of the Coralville formation.

Paragenesis of Calcite Generations

Figure 12 presents a tentative summary of the paragenetic relationships between the calcite phases considered in the preceding discussions of the unconformity separating the Coralville and Lithograph City formations. The nonluminescent to dully luminescent micrites (Figs. 5, 7, and 9), nonluminescent bladed palisade cements with ferric oxide inclusions (Figs. 10 and 11), and nonluminescent-luminescent zoned blocky equant spars (Figs. 5, 6, 7, 10, 11) are interpreted to be relatively early diagenetic phases that were formed in vadose to proximal meteoric phreatic environments during the marine offlap that concluded deposition of the Coralville Formation.

The nonluminescent isopachous radiaxial calcite spars (Figs. 7, 8, and 9) and dully to brightly luminescent pelletal calcarenites (Figs. 9 and 11) are interpreted to be relatively late diagenetic phases that originally were formed in oxidizing shallow marine-phreatic environments (later altered in reducing phreatic environments) during the transgression of the Lithograph City Formation.

DISCUSSION

The observations reported here may be peculiar to the local paleogeographic and paleotopographic setting of the Coralville Formation. Southeastward progradation of the supratidal facies of the upper Iowa City Member abruptly ended a short distance to the southeast of Iowa City (Bunker and Witzke, this guidebook). Paleotopographic relief associated with the edge of this restricted marine carbonate platform gave rise to several important features that were formed during the regression that ended Coralville deposition.

The anomalously deep erosional incision of the "State Quarry" channel suggests that constructional (depositional) topography associated with the zero edge of the Iowa City Member may have marked an escarpment on the pre-Lithograph City erosional surface. The deep channel might have been cut back from that Iowa City edge/escarpment.

The abundance of sediment and spar-filled microkarstic features in the Iowa City Member in the type area is truly remarkable, and the development of this large-scale pore network might well be explained by proximity to a paleotopographic escarpment at the edge of the restricted marine carbonate platform. Regional microfacies analyses of the Coralville Formation are needed to more accurately define the geographic extent of these features.

Erosional features of the pre-Lithograph City surface have direct bearing on the interpretation of the "bladed" nonluminescent radiaxial calcite cements in the Iowa City Member of the Coralville Formation. Paragenetic relationships determined from carbonate fabrics (Fig. 12) correlate these cements with the marine transgression that initiated deposition of the Lithograph City Formation. The cross-bedded calcarenite facies of the State Quarry Member of the Lithograph City Formation were interpreted to be tidal channel deposits by Watson (1974), and the "State Quarry" channel must have focused tidal currents during transgression of the paleotopographic escarpment. The paleotopographic escarpment also would have served as a barrier to circulation of marine waters, and active circulation of oxidizing shallow marine phreatic waters through the paleokarstic void network would be expected in the area. This integrated depositional-erosional-depositional scenario is proposed to explain the origin of the marine radiaxial calcite cements in the Coralville Formation of the Iowa City area.

SUMMARY AND CONCLUSIONS

A reconnaissance cathodoluminescence (CL) petrographic investigation of the diagenetic fabrics in the Coralville Formation and the rocks straddling the contact with the overlying Lithograph City Formation reveals the following:

1) Contrasts between CL micrite fabrics in skeletal packstones from near the base of the Coralville and fenestral lime mudstones near the top of the Coralville are consistent with the shallowing-upwards depositional trend proposed by Witzke et al. (1988). Lower Coralville muds were stabilized in either reducing marine-phreatic or reducing distal meteoric-phreatic environments, whereas upper Coralville muds were stabilized in an oxidizing to reducing proximal meteoric setting.

2) Contrasts between CL fabrics in upper Coralville limestones and immediately overlying pelletal calcarenites in the basal Lithograph City are consistent with the depositional asymmetry proposed for T-R cycles in the Cedar Valley Group (ibid.). Uppermost Coralville strata record diagenesis in vadose and oxidizing to reducing proximal meteoric phreatic environments, while overlying strata of the basal Lithograph City were stabilized in either reducing marine phreatic or reducing distal meteoric phreatic environments.

3) Nonluminescent isopachous radiaxial calcite spars filling microkarstic voids in the Iowa City Member of the Coralville Formation are not related to early diagenetic processes coeval with deposition of the hosting formation. They are interpreted to be shallow marine cements that were precipitated in a karstic void network during the intitial transgressive phase of deposition of the overlying Lithograph City Formation.

4) Diagenetic features of the carbonates in the Devonian Cedar Valley Group lend credence to the interpretations of T-R depositional cycles proposed by Witzke et al. (1988). Accordingly, each individual T-R formation is deserving of more intensive study. A wealth of research opportunities pertaining to the diagenesis of the Cedar Valley Group invite further attention.

ACKNOWLEDGMENTS

I am indebted to Brian Witzke and Bill Bunker for all that they have taught me about the Cedar Valley Group over the last several years. They generously donated sample NL-B from the "North Liberty Beds" area west of the Coralville Reservoir, and this sample proved to be very important in unraveling the diagenetic features associated with the Coralville-Lithograph City contact. I thank Brian Glenister and Paul Garvin for bringing to my attention the remarkable bladed spars exposed in the Coralville Formation at Conklin Quarry. Orrin Plocher loaned a polished thin section of skeletal packstone from the lower Coralville Fm. Orrin Plocher, Brian Witzke, and Bill Bunker are acknowledged for many useful discussions on the deposition and diagenesis of Cedar Valley carbonates. Finally, I thank Luis Gonzalez, Brian Witzke, Bill Bunker, and Orrin Plocher for their prompt reviews of this manuscript.

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INVESTIGATION OF THE MIDDLE PALEOZOIC APPARENT POLAR WANDER PATH FOR CRATONIC NORTH AMERICA

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The current gap in the mid Paleozoic apparent polar wander path (APWP) record of the Middle Devonian leaves unanswered questions concerning both plate motion and paleogeography during this time. The major purpose in acquiring Middle Devonian paleomagnetic data is to establish a reliable cratonic pole in an effort to fill this important gap. Previous Appalachian studies have had similar objectives, but all have shown remagnetized directions, the result of the Permian overprint.

Our study focuses on the Middle Devonian units of the stable craton in an effort to avoid the conditions which caused remagnetization of samples in previous work. All 9 prior studies are located along the east coast, and were therefore subjected to post-depositional lateral deformation. Although lack of deformation eliminates one major cause of remagnetization, another possibility is remagnetization due to fluid migration, the direct result of orogenic tectonism. Paleozoic carbonates adjacent to the Appalachians have shown a Permian overprint, believed to be the result of fluid migration. In studying the central craton from Iowa up though north-central Canada, the hope is to avoid such an effect due to the great distance from the tectonically active regions.

At this point only a few samples from one site in north-central Iowa have been analyzed (Fig. 1 - site 89D15). Figure 1 also shows the remaining sites collected that have not yet been analyzed, which include sites throughout the Wapsipinicon and Cedar Valley groups. Minor sampling was also done in Upper Ordovician strata for further reference. The site analyzed thus far was taken in the Spillville Quarry, with samples from the Spillville Formation of the Wapsipinicon Group, just above the Ordovician/Devonian unconformity. The shallowing-upward carbonate sequence present is similar to that of the Otis Formation in east-central Iowa (the stratigraphic equivalent of the Spillville Formation to the north). The stratigraphic section utilized was obtained from the Geological Society of Iowa Guidebook No. 39 (Bunker et al., 1983; see also Witzke et al., 1988 for revised stratigraphic terminology).

As expected, the carbonates have shown very weak magnetization, with an average intensity of 5.27e10-8 emu/cc and a range of 1.09e10-8 to 1.27e10-8 emu/cc. Although very weak, the samples are extremely magnetically stable, as indicated by low Q values. Thermal demagnetization has isolated three components of magnetization (Fig. 2). The first and greatest magnetically (referred to as component 3) is that of the present day field. Consistent with the Tertiary, it has a mean direction of declination = 15.9, inclination = 72.3. The second component unambiguously corresponds to the Permian overprint. As seen in the APWP of Figure 3, the second component lies near the Permian pole. This component, corresponding to the Kaiman Reversed Interval, has a mean direction of declination = 151.1, inclination = -11.0, and is what we had hoped to avoid in sampling the stable craton in Iowa. The final and characteristic component (referred to as component 1) is statistically distinct at the 95% confidence level from the second component. Therefore, although the Permian overprint is present, it was not strong enough to destroy a characteristic component which resides in magnetic grains with higher blocking temperatures.

Early results are encouraging, as preliminary directions show a characteristic component different from the ubiquitous Permian overprint. This remaining component means that there is a direction contained in the samples which is more magnetically stable than the Permian overprint. If this final direction turns out to be Middle Devonian in age, a significant gap will be filled in the APWP record of North America. At this point in our study, though, we require more

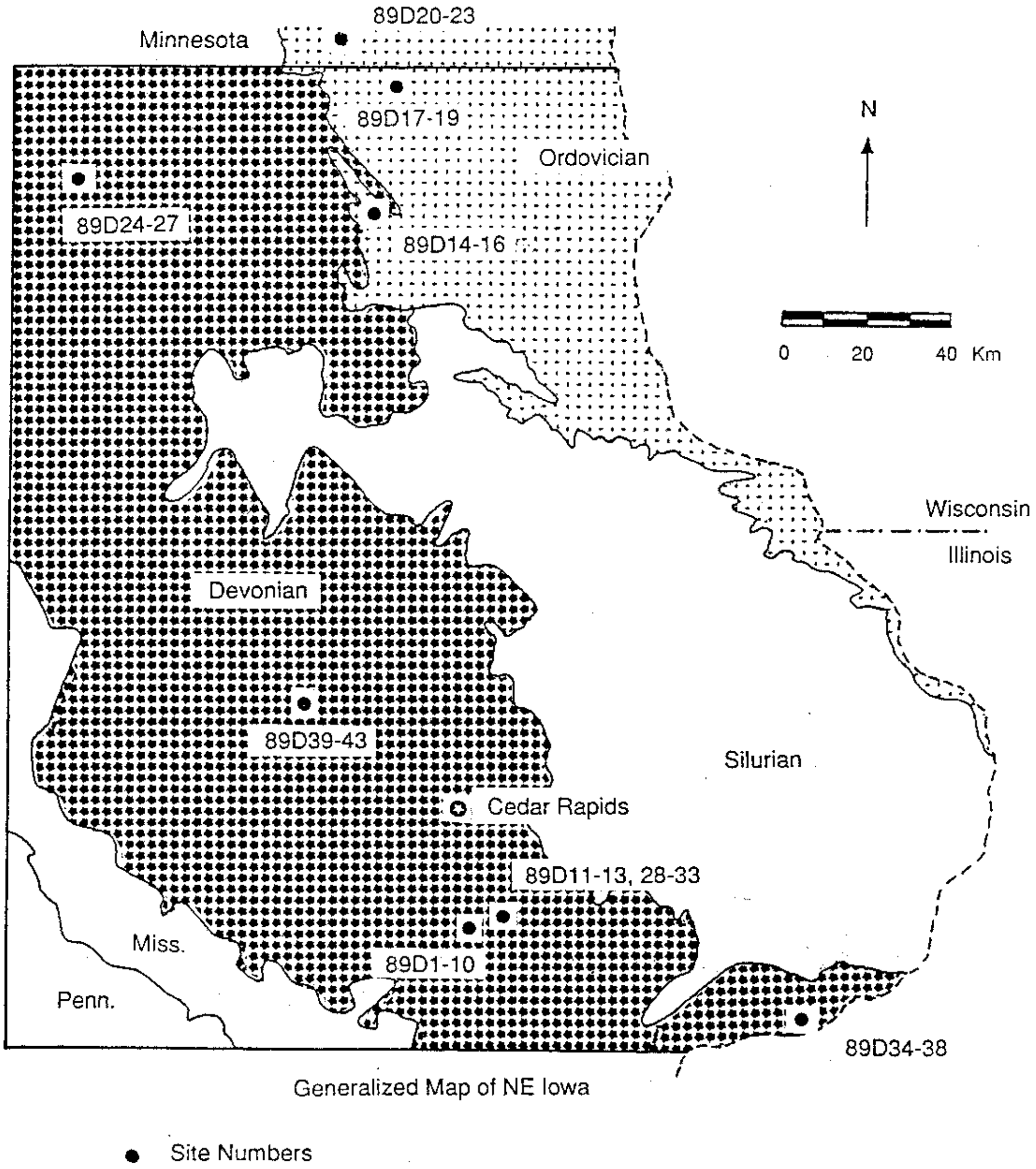

Figure 1. Site locations.

results before we make an age assignment to the characteristic component.

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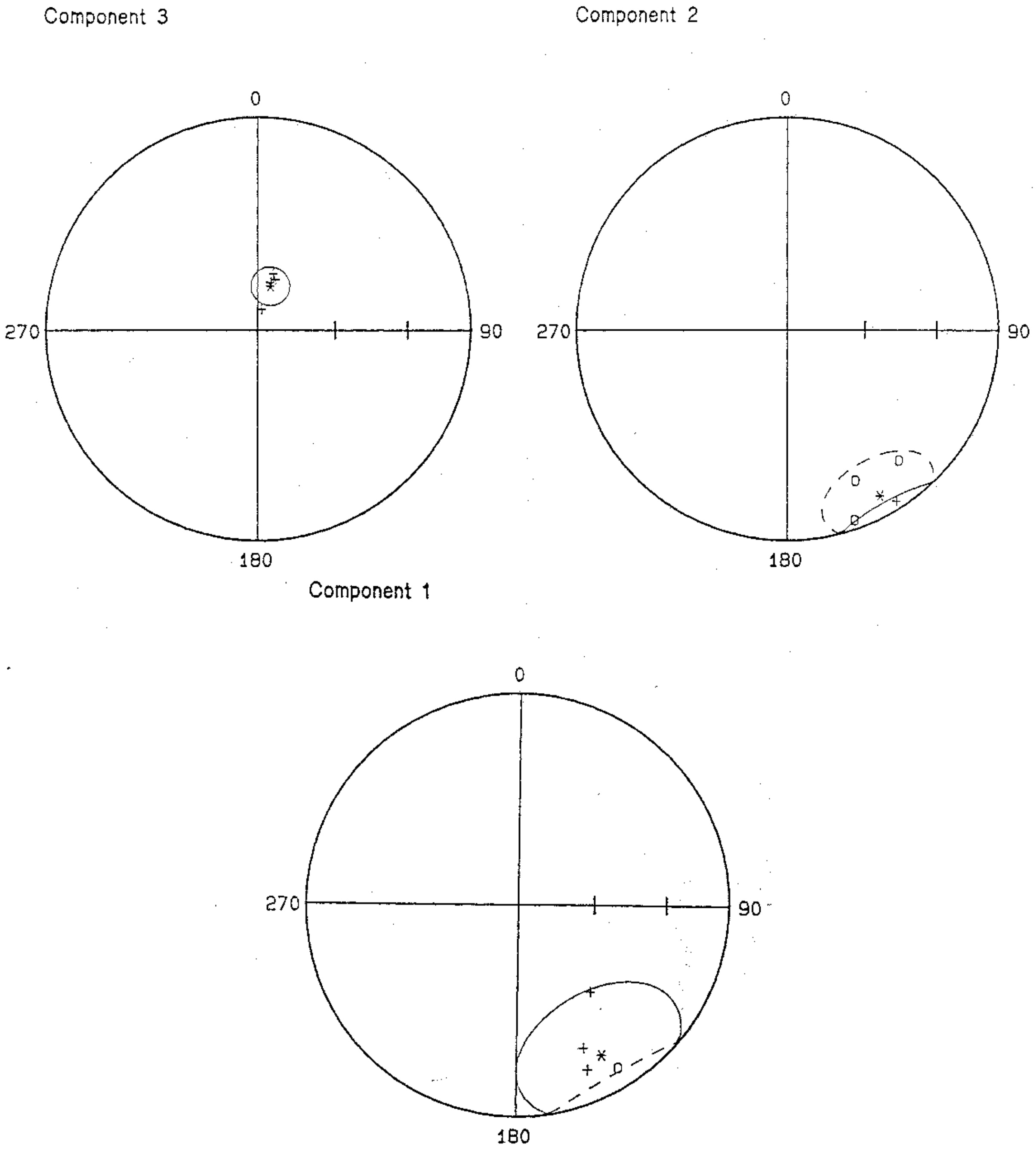

Figure 2. Magnetic directions of the three different components of magnetization.

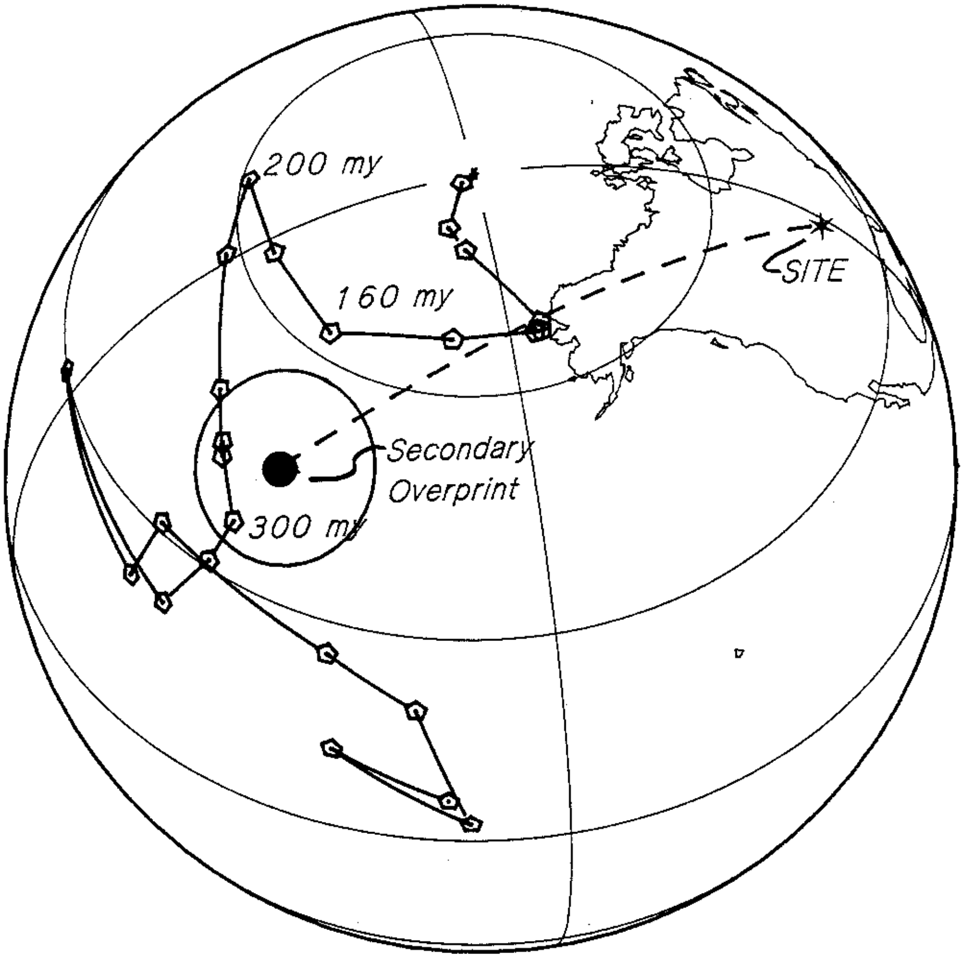

Figure 3. Apparent polar wander path for North America.
* site in Iowa
o pole direction of the Iowa site
⬠ magnetic poles in 20 million year intervals

PENNSYLVANIAN ROCKS IN JOHNSON COUNTY IOWA

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INTRODUCTION

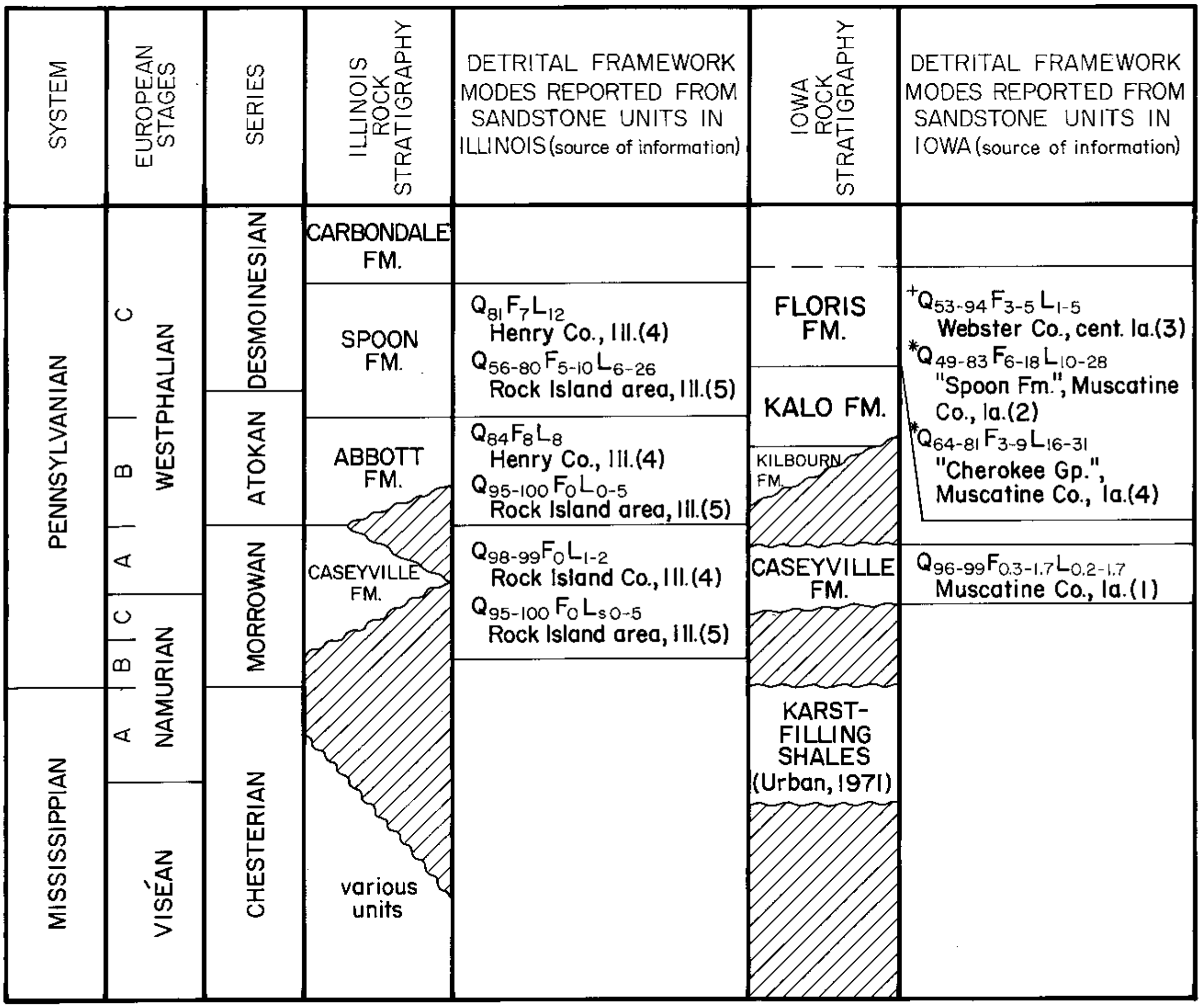
Prior to the deposition of rocks in the Pennsylvanian System, Midcontinent North America was subject to a long period of continental emergence, during which earlier Paleozoic and Precambrian rocks were deeply eroded. The rocks of the Pennsylvanian System that buried the pre-Absaroka erosion surface were deposited during a series of cyclic rises and falls of sea level that resulted in a complex succession of alternating marine and nonmarine sedimentary rocks (Ravn et al., 1984). The basal units in the succession generally are interbedded sandstones and mudstones that were deposited by stream systems in coastal lowland areas. These include rocks of the Lower Pennsylvanian (Morrowan) Caseyville Formation and Middle Pennsylvanian (Atokan-Desmoineisan) rocks of the Cherokee Group (ibid.).

Pennsylvanian outliers (mostly sandstones) are widely distributed across eastern Iowa as isolated erosional remnants of a once-continuous sedimentary cover (Bunker et al., 1985). Correlations of the basal Pennsylvanian rocks in these outliers have considerable importance for regional and local interpretations of the Pennsylvanian paleogeography and paleotectonics of the Upper Mississippi Valley. Recently published studies have shown that Morrowan strata of the Caseyville Formation are more widely distributed across Iowa than was previously believed (Ludvigson, 1985, 1988; Nations, 1988, 1989). Continuing research efforts show promise that the stratigraphic correlations of isolated Pennsylvanian outliers may be approached by use of multiple criteria, including palynostratigraphic studies and petrographic studies of detrital modes of sandstones (ibid.; Scal et al., 1989). A summary of compositional attributes from Morrowan, Atokan, and Desmoinesian sandstones is shown in Figure 1.

DETRITAL MODES OF SANDSTONES EXPOSED IN JOHNSON COUNTY

Exposures of Pennsylvanian-age sandstones around Coralville Lake frequently are spatially associated with the incision of modern drainages into the Devonian-age limestones (see comments by Bettis in this guidebook). These sandstones were originally deposited in ancient drainage channels that also were cut into the underlying Devonian rocks, and their control on the modern drainage network demonstrates that they are less resistant to erosion than the underlying and adjacent Devonian limestones. Pennsylvanian channel fills in Johnson County include two compositionally distinct groups that accumulated during at least two separate depositional episodes. The erosive characteristics and outcrop expression of both groups are quite similar, so that they may not be readily distinguished without supporting laboratory studies.

The first group consists of Early Pennsylvanian fine- to medium-grained quartzose sandstones that are best known from studies of channel fills in the Conklin Quarry (Fig. 2), located to the south of the Coralville Dam (Ludvigson, 1985). The sandstones at Conklin Quarry consist almost entirely of detrital quartz grains with lesser quantities of mostly sedimentary rock fragments. These compositional attributes suggest affinities to the Caseyville Formation, and also to the Atokan Abbott Formation in the Quad Cities Illinois-Iowa area (Fig. 3) The detrital modes in these rocks clearly do not resemble those expected from the Desmoinesian Spoon Formation in the Quad-Cities (Fig. 3) or younger Pennsylvanian strata in the Forest City Basin in Iowa (Scal et al., 1989). The medium-grained Pennsylvanian sandstones exposed near the entrance to Sugar Bottoms Public Use Area near Mehaffey Bridge also belong to this group (Fig. 3). This group of deposits are most reasonably included in the Caseyville Formation. Petrographic studies of the group have shown that



Sources of information on detrital framework modes:

1) Fitzgerald, 1977, p.35
2) Fitzgerald, 1977, p.48
3) Burrgraf *et al.*, 1981, p.43
4) Anderson *et al.*, 1982, p. 16-17
5) Isbell *et al.*, 1984, p.490

+Correlation suggested in Ravn *et al.*, 1984, p.28
*Correlation suggested in Ravn *et al.*, 1984, p.7

Figure 1. Stratigraphy of the basal Pennsylvanian rocks in Iowa and Illinois, with QFL (quartz-feldspar-lithic grains) serial designations, based on petrographic studies in Iowa and Illinois. From Ludvigson (1985).

they may occur as friable, clean quartz sandstones, and also as more erosionally resistant argillaceous sandstones, with detrital clay matrix ranging from 37 to 45% of the rock volume (Ludvigson, 1985). Microscopic study of such friable rocks requires prior stabilization by the vacuum injection of epoxide resin, because of their tendency to disintegrate during grinding and polishing.

The second group of sandstones in Johnson County consists of micaceous, arkosic units that are known from channel-filling exposures near the Mayflower Dormitory on the University of Iowa campus (Witzke and Kay, 1984). These rocks reportedly average about 27% feldspar sand grains (ibid.). Rocks from this group are most reasonably correlated with Desmoinesian units in the Cherokee Group. The Mayflower exposures

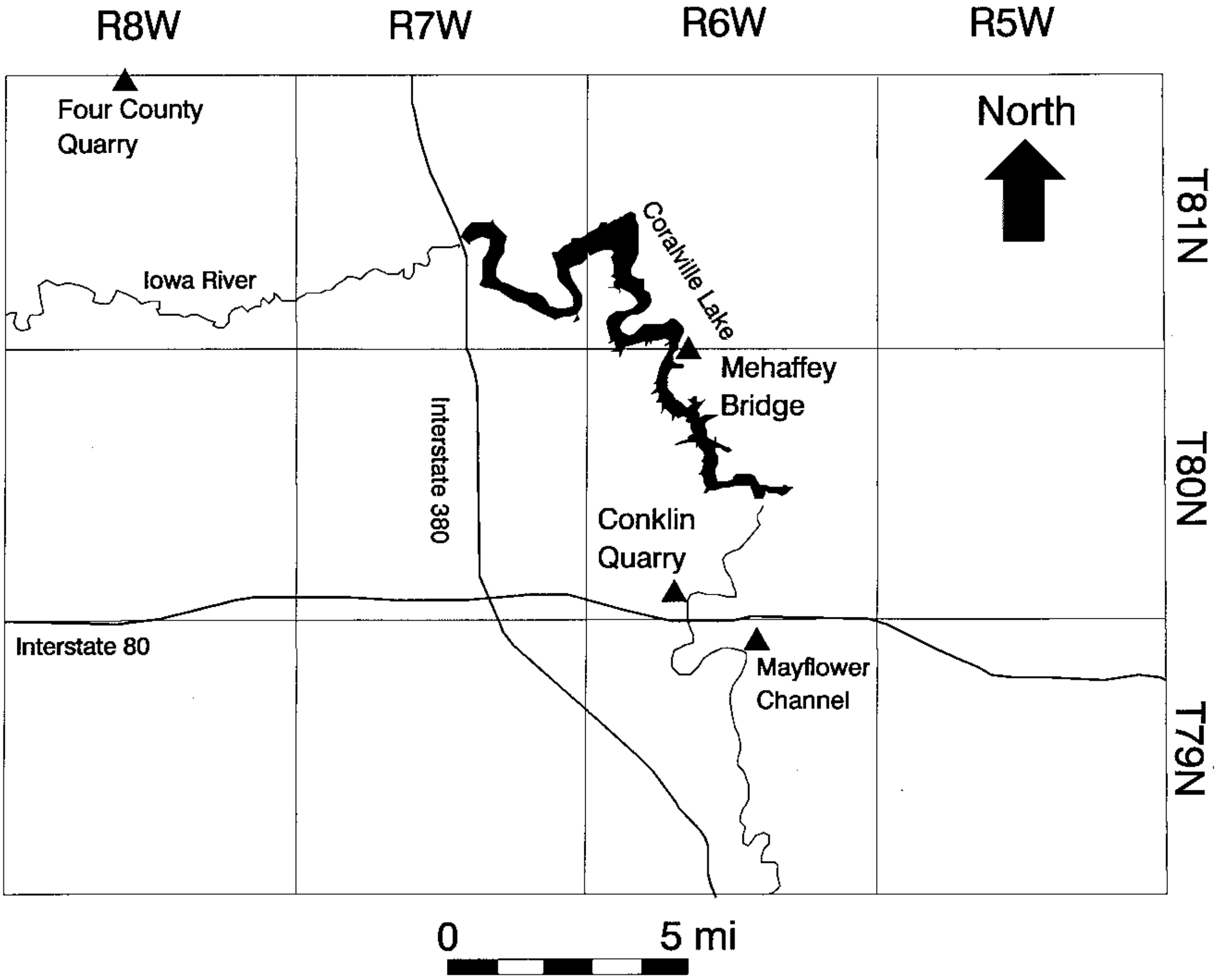


Figure 2. Location map for exposures of Pennsylvanian strata in Johnson County, Iowa.

include laminated fine-grained sandstones that were used for building stones in the early history of Iowa City (Witzke, 1984). The breakdown of chemically unstable sand grains and pyrite cements, and the laminated structure of these old building stones are the probable cause of their tendency to rapidly disintegrate on weathering. Consequently, their use was abandoned after the mid 1800's (ibid.).

PALYNOLOGY OF PENNSYLVANIAN KARST FILLS IN JOHNSON COUNTY

Paleokarst fills in Conklin and Four County quarries (Fig. 2; see Garvin and Ludvigson, 1988) were sampled and processed for palynomorphs to determine the age of the fill deposits. The deposits from both quarries contained spores which are Early Pennsylvanian in age. The spore assemblage from each site was found to be dominated by lycopsid-type spores, such as *Lycospora* and *Densosporites*, indicating the presence of Pennsylvanian-age scale-bark trees at the time the sediments were deposited. Lycopsid-type spores are known to dominate Morrowan-age spore assemblages (Ravn, 1986), and similar assemblages have been found at other localities around the state (Nations, 1988, 1989; Ravn and Fitzgerald, 1982).

Conklin Quarry samples, which vary in content, were taken from several beds within the

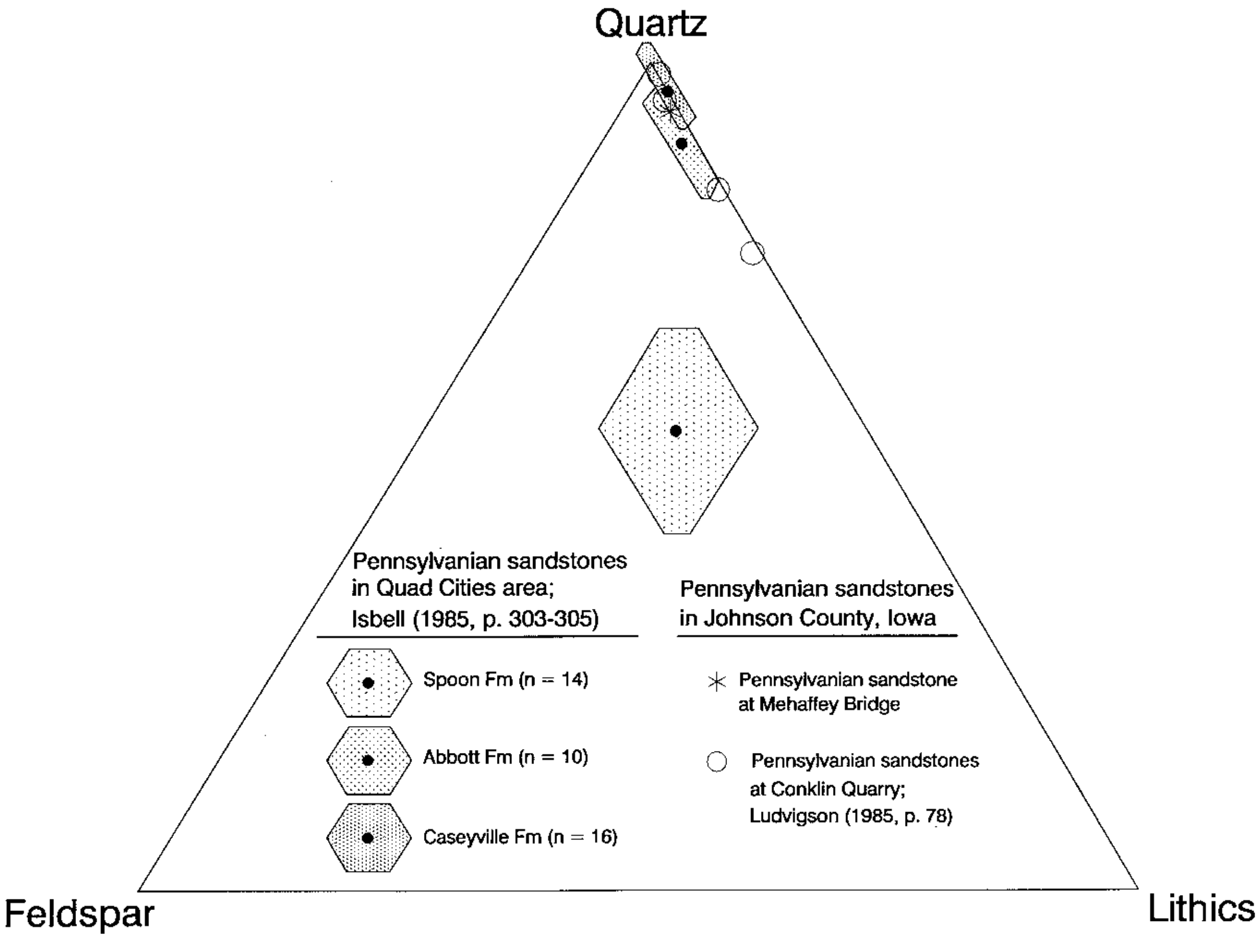


Figure 3. QFL plot for Pennsylvanian sandstones in Johnson County, in comparison with well-studied Morrowan, Atokan, and Desmoinesian sandstones from the Quad-Cities Illinois-Iowa area. Hexagons are centered about the mean compositions, and standard deviations from the mean for each grain parameter determine the shapes of the hexagons.

karst fill. A sample from a carbonaceous shale contained the most abundant floral assemblage. This sample contained the species *Densosporites variabilis*, an indicator of Morrowan deposits, which was also found in the Four County Quarry. Other beds within the karst fill contained spores that are known from early Pennsylvanian deposits, but did not contain spores specific to the Morrowan. Modern pollen was found in one sample, possibly indicating some contamination of sediments. Lower fill samples did not contain abundant or well-preserved spores, nor did those samples which contained pyrite. Although the carbonaceous shale sample is most probably Morrowan in age, the other beds within the fill can be dated only to Early to Middle Pennsylvanian deposits at this time.

The floral assemblage from the Four County Quarry contains *Densosporites variabilis*, *Radiizonates striatus*, and *Lycospora noctuina*, species which previously have been found only in Morrowan age deposits (Ravn, 1986). Other lycopsid-type species include *D. irregularis*, *D. sphaerotriangularis*, *Lycospora pellucida*, and *L. micropapillata*. Lycopsid species dominate the assemblage, whereas low numbers of fern and gymnosperm species are present.

Since karst fills from both Conklin and Four County quarries, as well as other paleokarst deposits in Linn and Muscatine counties (Bunker, et al., 1985) contain Morrowan spores, it is suggested that these sediments were preferentially preserved in paleokarsts. Morrowan strata superposed on the sub-Pennsylvanian erosion surface are rare in eastern Iowa, suggesting that most of the Morrowan land surface was well above local base level, and/or that widespread Early Pennsylvanian deposits were removed during a post-Morrowan, pre-Demoinesian erosional episode.

CONCLUSIONS

New data on the Pennsylvanian rocks in Johnson County indicate that Early Pennsylvanian strata are more widely preserved across eastern Iowa than was previously believed. Morrowan deposits are common in paleokarst fills, but also appear to be superposed on the sub-Absaroka erosion surface at many localities. These results indicate that the isolated outliers of Pennsylvanian rocks scattered across eastern Iowa may yet provide more useful information on the Early-Middle Pennsylvanian paleogeography of the Upper Mississippi Valley.

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LATE QUATERNARY HISTORY OF THE IOWA RIVER VALLEY IN THE CORALVILLE LAKE AREA

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INTRODUCTION

The Iowa River valley is one of Iowa's major interior valleys. It heads along the late Wisconsinan Algona and Altamont End Moraine complexes in north-central Iowa, skirts the southern boundary of the Iowan Surface in east-central Iowa, then passes through the Southern Iowa Drift Plain and Lake Calvin Basin before its junction with the Mississippi River valley in southeastern Louisa County. Along the way the character of the valley changes in relation to its age, history, and the nature of the materials into which it is carved. On the Des Moines Lobe in central Iowa the valley is Wisconsinan in age and bears the imprint of glacial meltwater events. In Wright and Hancock counties the valley is ice-marginal. Here the valley is shallow and contains kettled outwash terraces. Between Alden and Iowa Falls in Hardin County the valley remains shallow and contains low-relief sandy and gravelly outwash terraces. The valley becomes more deeply entrenched and begins to take on the form of a narrow gorge as it cuts into Mississippian rocks at Iowa Falls. The Iowa Valley passes off the Des Moines Lobe at Steamboat Rock in eastern Hardin County and continues southward as a gorge deeply incised into the Pre-Illinoian till sequence and underlying Pennsylvanian sandstone. After joining with the South Fork downstream of Eldora near Gifford the Iowa Valley begins to broaden and takes on characteristics typical of the valley along the southern margin of the Iowan Surface in Marshall, Tama, Iowa, and Johnson counties. From here to its junction with the Mississippi Valley the Iowa Valley is pre-Wisconsinan in age. Along the southern margin of the Iowan Surface the valley is broad, deeply entrenched into the upland, and usually has a loess-mantled terrace flanking one of the valley walls. Deviations from this morphology occur where the valley is constricted by bedrock at LeGrand in Marshall County (Mississippian rocks) and in the Coralville Lake area (Devonian rocks). In north-central Johnson County the valley cuts diagonally across an extensive buried bedrock valley system before crossing onto a bedrock high and forming the Iowa River Gorge from Coralville Lake to Iowa City (Hansen, 1972). Immediately south of Iowa City the valley widens significantly and once again contains broad tracts of loess-mantled terraces. In the junction areas of Johnson, Muscatine and Louisa counties, the Iowa and Cedar valleys merge and include an extensive area of relatively level high terraces that extend down valley almost to the Mississippi Valley. This is the so-called Lake Calvin Basin, once thought to be the site of extensive Illinoian ice-dammed lakes, but today recognized as an extensive complex of Wisconsinan and pre-Wisconsinan Iowa and Cedar Valley terraces.

Although bedrock-constricted parts of the Iowa Valley, such as the Coralville Lake area, are rare the Quaternary upland and valley deposits preserved around and within this part of the valley can be related to those found upstream and downstream. The following discussion relates the Quaternary deposits in the Coralville Lake area to both the regional lithostratigraphy of eastern Iowa and the localized valley lithostratigraphy in the lower Iowa and Cedar River basins.

QUATERNARY DEPOSITS

The Quaternary lithostratigraphy of eastern Iowa is based on the stratigraphy of Pre-Illinoian glacial tills and Wisconsinan loesses because these deposits are regional in extent and provide "marker" units to which more localized fluvial and colluvial units can be stratigraphically related. Recent investigations (Hallberg, 1980; 1986; Hallberg (ed.), 1980) have substantially revised the stratigraphy of Pre-Illinoian tills in Iowa. Since all these tills look similar in the field,

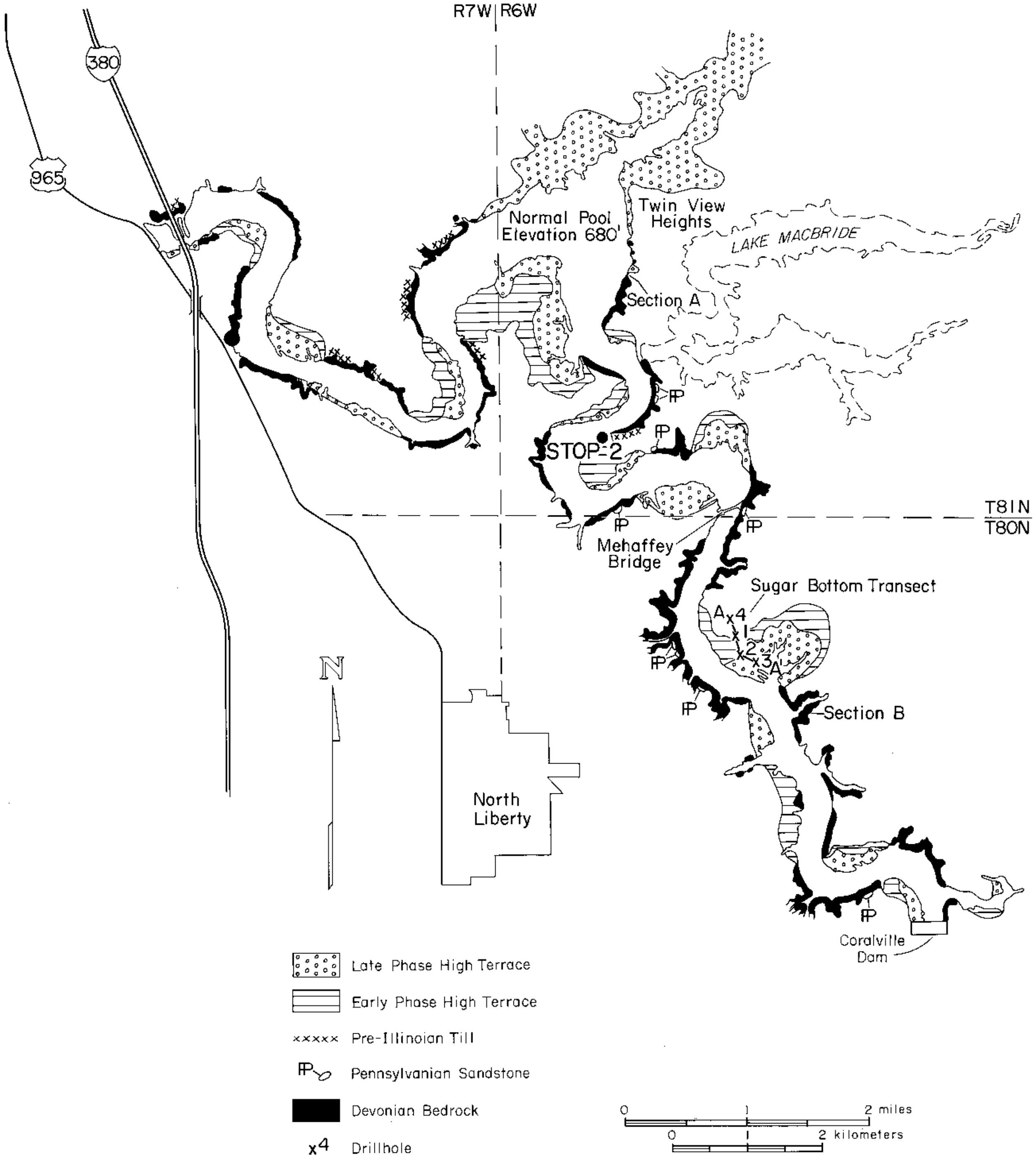

Figure 1. Map showing the distribution of Iowa Valley terraces in the Coralville Lake area. Also shown are large outcrop areas of Pre-Illinoian till and Pennsylvanian sandstone. Sections A and B, the Sugar Bottom Transect, and STOP 2 are discussed in the text. (adapted from Bettis and Ludvigson, 1988).

previous subdivisions of the tills were based solely on relationships to buried soil (paleosol) "markers".

Detailed outcrop and subsurface investigations on a regional scale combined with extensive laboratory work and careful synthesis and reevaluation of previous work has resulted in the abandonment of the classical glacial and interglacial terms: Kansan, Aftonian, and Nebraskan (Hallberg, 1986). This work demonstrated that the buried soil markers that had been used to distinguish the glacial deposits were frequently miscorrelated and that there is a much more complex sequence (i.e., more tills, more glaciations, and more buried soils) than previously recognized. Today all Quaternary deposits in the Upper Midwest older than Illinoian are referred to in a time-stratigraphic sense as Pre-Illinoian Stages, undifferentiated.

Pre-Illinoian lithostratigraphic units are characterized and correlated on the basis of laboratory-derived lithologic properties. Pre-Illinoian tills are divided into two formations, the Wolf Creek Formation, and the older Alburnett Formation on the basis of differences in clay mineralogy. Both formations are dominated by expandable (smectite) minerals in the clay fraction, but the Wolf Creek Formation has a much higher percentage of expandable clay minerals (averaging 60 percent) than the Alburnett Formation (averaging 45 percent). Each formation consists of multiple till units and paleosols. Regional studies indicate that at least seven major periods of glaciation occurred in Iowa during the Pre-Illinoian, beginning as early as 2.2 million years ago and ending about 500,000 years ago. The Alburnett and Wolf Creek formations are lithostratigraphic units and do not correspond to time-stratigraphic units such as Kansan and Nebraskan. The multiple tills and paleosols in the Pre-Illinoian sequence indicate numerous glacial and interglacial stages during what were formerly classified as the Nebraskan, Aftonian, and Kansan stages (Boellstorff, 1978; Hallberg, 1980; 1986). The River Products Quarry (Conklin Quarry) in Iowa City, site of the 1984 GSI Spring fieldtrip, contains an excellent exposure of much of the Pre-Illinoian till and paleosol sequence (Bunker and Hallberg, 1984).

Regionally extensive upland units were not deposited in the Coralville Lake area between about 500,000 to 30,000 years ago. During this interval several episodes of landscape development involving entrenchment of the drainage network, erosional development of slopes, and soil formation on relatively stable landscape elements took place. Very little is known of the early evolution of eastern Iowa's drainage network. Few, if any, deposits that accumulated between about 500,000 and 300,000 years ago are preserved.

Approximately 300,000 years ago glacial ice advancing from the northeast entered southeastern Iowa and advanced about 25 miles into Scott, Muscatine, Louisa, and Des Moines counties (Hallberg et al., 1980). This was the only advance of the Illinoian glaciation into Iowa.

The youngest regionally extensive Quaternary deposits in eastern Iowa are Wisconsinan loesses that were deposited between about 30,000 and 12,500 years ago. These are wind-blown deposits that mantle uplands and older terraces throughout much of Iowa (Ruhe, 1969; Prior, 1976). The loesses are sometimes interbedded with local eolian sand and colluvial deposits. Where the full eolian sequence is preserved, two loesses are present: a very thin lower unit (stratigraphically equivalent to the Roxana Silt in Illinois), and a markedly thicker upper unit (Peoria Loess). In the Coralville Lake area the Roxana Silt equivalent (RSE) varies from 1.0 to 3.0 ft. in thickness, is leached of primary matrix carbonates, and has a poorly expressed soil (known as the Farmdale Soil) developed into it. The Roxana Silt equivalent accumulated in Iowa between about 30,000 and 24,000 years ago, and the Farmdale Soil developed in the upper part of the RSE between about 24,000 and 21,000 years ago on stable parts of the landscape. The overlying Peoria Loess ranges from 6 to 30 ft. in thickness and has the modern soil developed in its upper part. Peoria Loess began to accumulate on stable portions of the landscape between 25,000 and 21,000 years ago in eastern Iowa.

Between about 21,000 and 17,000 years ago, during the coldest part of the Wisconsinan glacial episode, extensive upland erosion took place throughout much of the Upper Midwest. In eastern Iowa this erosion led to the evolution of a distinctive landform area known as the Iowan Surface (Prior, 1976). During this period of extensive erosion, surface soils were removed from most of the Iowan Surface and the sequence of Pre-Illinoian tills was severely eroded, leaving behind a lag deposit of erratics referred to as a stone line.

Following the Illinoian glaciation extensive alluvial deposits accumulated in the valleys of eastern Iowa. Esling (1984) studied these deposits in the lower reaches of the Iowa and Cedar valleys (the Lake Calvin Basin) and identified three assemblages of terrace deposits that have different stratigraphy and ages. The Early Phase High Terrace (EPHT) is mantled with both the RSE and Peoria Loess and has a well-expressed soil, the Sangamon Soil, developed the upper part of the sub-loess alluvium. Deposits comprising this terrace are older than about 40,000 B.P., but younger than the Illinoian till in southwestern Iowa (Esling, 1984). Deposits of the Late Phase High Terrace (LPHT) are inset into, and sometimes overlap, the older EPHT. Only the Peoria Loess mantles LPHT deposits. The loess grades downward into the alluvium comprising this terrace with no intervening paleosol (ibid.). LPHT deposits began to accumulate before 25,000 B.P. and were buried by Peoria Loess before 12,500 B.P. The youngest terrace assemblage identified by Esling is the Low Terrace (LT). This group of terrace deposits is not mantled with Wisconsinan eolian deposits. Deposits comprising the bulk of the LT group accumulated between about 12,000 and 10,000 years ago.

The extensive alluvial deposits comprising the EPHT, LPHT, and LT resulted from the development of erosion surfaces in boardering upland areas. Deposits of the EPHT were derived from several episodes of upland erosion during which many erosion surfaces collectively referred to as Sangamon and "Late Sangamon" developed (Ruhe et al., 1967; Bettis et al., 1984). These erosion surfaces and corresponding valley deposits predate accumulation of the RSE (approximately 30,000-24,000 B.P.) but postdate the earliest Illinoian glaciation. LPHT deposits are depositionally related to the Iowan Surface on the uplands. Peoria Loess grades downward into this alluvium indicating that the top of the alluvium is older than 12,500 B.P. but younger than 25,000 B.P. LT deposits are latest Wisconsinan and early Holocene in age and do not have a loess cap. The bulk of these deposits are distal outwash that accumulated during and shortly after wastage of the Des Moines Lobe glacier in central Iowa.

CORALVILLE LAKE EXPOSURES

Oxidized and leached Pre-Illinoian till is intermittently exposed along the Coralville Lake shoreline (Fig. 1). The mapped distribution of these deposits shows only the largest and most extensive outcrops. Many other small outcrops are present, but because of scale limitations, they are not shown on this map. The Pre-Illinoian deposits in these exposures are eroded and weathered and are not easily assigned to one of the two Pre-Illinoian formations because their original clay-mineral assemblage has been altered (weathered). All outcrops of Pre-Illinoian till observed downstream of I-380 are several tens of feet above average lake level (680 ft.) and unconformably overlie Devonian rocks. At Section A, just downstream of Twin View Heights along the eastern valley wall, striations produced by glacial ice pushing lodged rocks across the bedrock surface are evident (Fig. 1). Orientation of the striations ranges between 55 and 68 degrees west of north. Several other outcrops of Pre-Illinoian till were observed along the shore line. In some of these exposures thin deposits of gravel lie beneath the Pre-Illinoian till and rest on the bedrock surface. Thick deposits of both the Wolf Creek and Alburnett formations are present in the buried bedrock valley system cut diagonally by the present Iowa Valley upstream of I-380 in the western part of the Hawkeye Wildlife Area (Hallberg, 1980). In some shoreline exposures a paleosol (Sangamon Soil) is developed in the upper part of the Pre-Illinoian deposits, while in other exposures the paleosol is absent, having been erosionally removed during development of the Iowan Surface. Sections that exhibit a paleosol developed in Pre-Illinoian till also have both the RSE and the Peoria Loess (Fig. 2). Sections that do not have a paleosol developed in the till surface are missing the RSE but do exhibit Peoria Loess, eolian sand, or both overlying the eroded till surface.

Rare exposures of old, high-level gravelly alluvium with a reddish brown paleosol developed into it are present along the valley wall downstream of I-380. An example of this alluvium is present at Section B (Fig. 1) where the base of the old alluvium is 18 feet above average lake level. The surface of the underlying Devonian rocks is weathered and pockets of dark brown

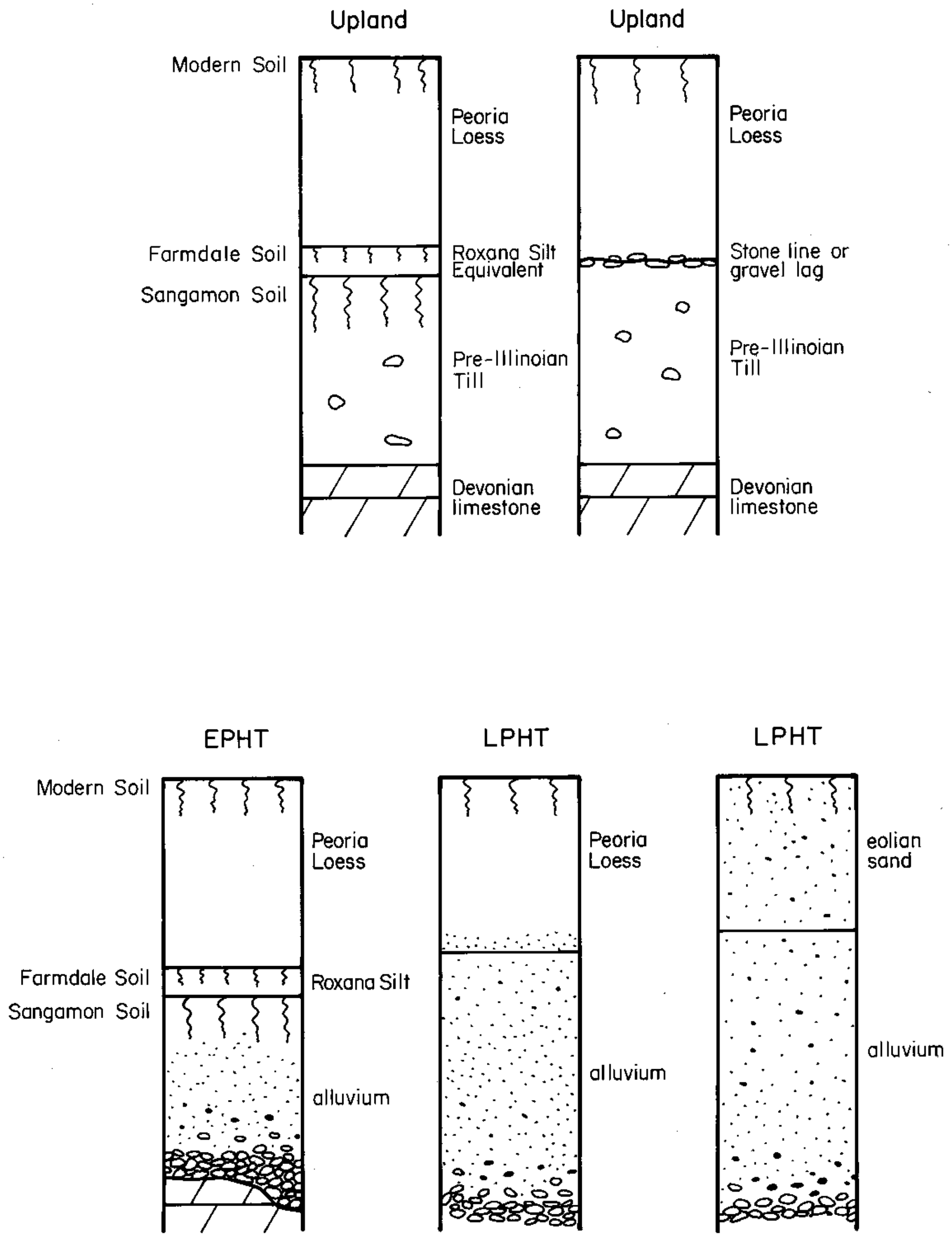

Figure 2. Typical sequences of Quaternary deposits exposed along the shoreline of Coralville Lake. The upland sequence on the left is typical in the Southern Iowa Drift Plain while that on the right is typical in the Iowa Surface landform region. See text for explanation of the deposits.

clay loam residuum enclosing silicified Devonian fossils are present in low spots on the rock surface. Eight feet of very weathered sand and medium to coarse gravel with a reddish brown paleosol developed into its upper part overlie the rock surface. The paleosol is overlain by both the RSE and Peoria Loess. These old alluvial deposits may be related to early phases of the development of the Iowa Valley, but their limited preservation makes interpretation of their relationship to the present valley problematic.

Many of the shoreline exposures along Coralville Lake reveal alluvial deposits related to the Iowa River valley. These alluvial deposits truncate, and are therefore younger than, the Pre-Illinoian till along the valley margin. Figure 3 is a cross-section constructed from drill-hole data in the Sugar Bottom Public Use Area. The cross-section extends from the upland down to the alluvial fill sequence, and shows typical relationships among the various Quaternary units in the Coralville Lake area downstream of I-380.

The oldest mappable terrace deposits in the area are correlated with Esling's (1984) EPHT deposits of the lower Iowa and Cedar valleys. These deposits consist of sandy and gravelly alluvium fining-upward and into which a reddish brown-colored paleosol (the Sangamon Soil) has developed in the upper part (Fig. 2). In a few exposures another reddish brown paleosol is developed within the alluvium. The alluvial deposits and paleosol(s) are buried by both the RSE and Peoria Loess. The EPHT is between about 750 and 720 feet in elevation in the Coralville Lake area downstream of I-380. At STOP 2 we will visit an exposure of EPHT deposits and overlying Wisconsinan eolian deposits.

Exposures of tributary valley fills related to the EPHT are present in this part of the Iowa valley. The exposures show alluvium with one or more reddish brown paleosols buried by both increments of Wisconsinan eolian deposits. The bases of these small valley fills are higher in elevation than the main valley EPHT fill. These small valley fills are contained within U-shaped valleys cut into underlying Pennsylvanian and Devonian rocks. The location of many of the small tributary valleys in the gorge area is coincident with outcrops of Pennsylvanian sandstone. This coincidence may be a result of the lesser erosional resistance of the sandstone relative to the Devonian limestone as well as seepage effects from shallow groundwater passing through the more porous sandstone.

Younger terrace deposits are inset into the EPHT deposits. Outcrops of these deposits are common along the shoreline and expose sandy alluvium overlain by Peoria Loess or eolian sand. No paleosol intervenes between the eolian deposits and alluvium comprising this terrace (Figs. 2 & 3). An eolian-sand mantle on this terrace is very common upstream of Lake MacBride in the area where Hoosier Creek enters the Iowa Valley, and in the Sandy Beach Public Use Area. These terrace deposits are correlative with Esling's (1984) Late Phase High Terrace (LPHT) downstream in the lower Iowa and Cedar valleys, and the Wisconsinan terrace mapped by Anderson (1986) in the Hawkeye Wildlife Area upstream of I-380. The LPHT encompasses two or more closely spaced, loess and eolian-sand-mantled terraces whose surfaces lie between about 710 and 685 feet in elevation downstream of I-380. The alluvium in the lowest of these terraces is below average lake level (680 ft.), and the top of the loess mantle is about 5 feet above it. An extensive area of LPHT exposure is present at and around the mouth of Hoosier Creek upstream of Lake MacBride. In this area much of the LPHT is mantled with eolian sand and natural sandy beaches (such as at the Sandy Beach Public Use Area) are common. Upstream of I-380 in the Hawkeye Wildlife Area the topographic distinction between the EPHT and LPHT has been blurred by late Wisconsinan and Holocene dune and sand-sheet activity.

Downstream of I-380 alluvial deposits younger than the LPHT are below lake level even at low lake stand. Upstream of I-380, Anderson (1986) delineated three terrace complexes younger than the LPHT. Anderson's Woodfordian High terrace in the Hawkeye Wildlife area is probably correlative with the Low Terrace complex of Esling. This terrace complex is below lake level downstream of I-380. Anderson's Intermediate and Low terraces are Holocene in age, and their correlatives are also below lake level downstream of I-380.

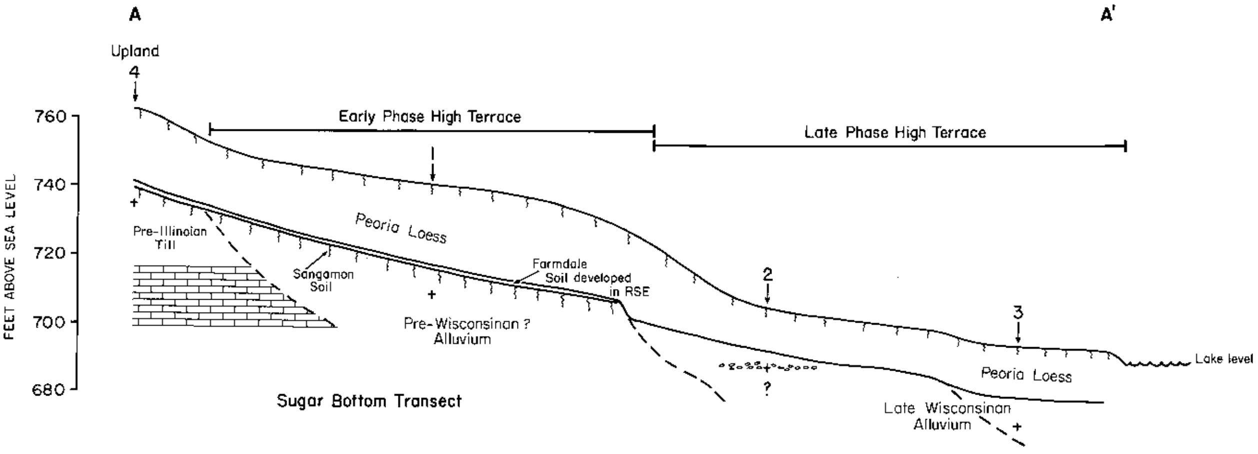

Figure 3. Cross-section of the sequence of Quaternary deposits in the Sugar Bottom Public Use Area. Stratigraphic relationships among the Quaternary units along this transect are typical of those found in the Coralville Lake area. Numbers with arrows beneath show the location of borings. Location of cross-section is shown on Figure 1. Vertical exaggeration 67X.

SUMMARY

Although the bedrock-constricted gorge of the Iowa Valley in the Coralville Lake and Iowa City areas is not typical of the Iowan Surface and Southern Iowa Drift Plain physiographically, it does exhibit stratigraphic relationships among upland tills and loesses and valley fills that are typical for eastern Iowa. Wisconsinan eolian deposits mantle uplands and alluvial deposits older than about 12,000 years B.P. Pre-Illinoian tills occur on upland areas and bury an extensive southwest-trending bedrock valley system that the Iowa Valley cuts across in the eastern portion of the Hawkeye Wildlife Area (Hansen, 1972). The oldest mappable alluvial fill in the valley is post-Illinoian and Pre-Wisconsinan in age and correlative with the Early Phase High Terrace of the lower Iowa and Cedar river basins. A lower late Wisconsinan-age terrace complex, corresponding to the Late Phase High Terrace downstream, is also precent in the Coralville Lake area. Deposits younger than about 11,000 years are below low lake level downstream of I-380 in Coralville Lake.

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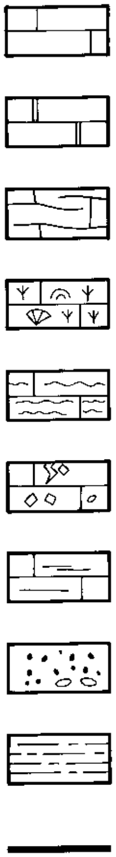
STOP DESCRIPTIONS AND DISCUSSIONS

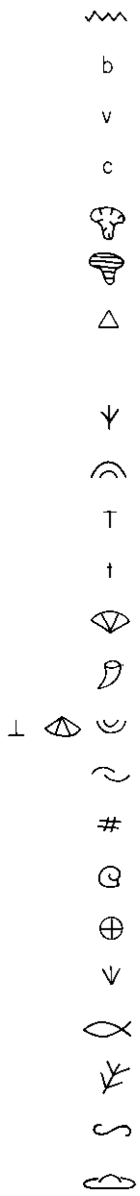
KEY

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 - MACBRIDE SPILLWAY

Discussion by Orrin W. Plocher, Bill J. Bunker, and Brian J. Witzke

Macbride Spillway was constructed to provide an overflow for Macbride Lake into Coralville Lake. Quarrying activity during construction of the spillway created an excellent exposure of the lower Little Cedar Formation (Solon and Rapid members). The Solon is exposed in the floor of the spillway on the south side, and along the Coralville Lake shoreline downstream from the spillway. Exposures along Coralville Lake are variably accessible, dependent upon the water level of the lake.

The entire north wall of the spillway exposes lower Rapid strata. The south wall also exposes the lower Rapid Member except for the lowest meter or so which is uppermost Solon Member.

Lower Solon lithologies exposed along the Coralville Lake shoreline below the spillway include skeletal wackestones and packstones, with diverse open-marine biotas. The upper part of the Solon Member exposed in the floor of the spillway consists of coralline-stromatoporoid rich packstones. Excellent weathered bedding plane surfaces form coral-stromatoporoid pavements in the spillway floor near the south side.

Lower Rapid Member lithologies are a repetition of skeletal wackestones separated with thin very argillaceous partings. These rocks are best observed in the south wall due to structural complications in the north wall. Higher in the south wall thin very agrillaceous beds become thicker and are variably fossiliferous to very sparsely fossiliferous. Above these sparsely fossiliferous units, exposed only at the top of the north face, is the lower coralline biostrome of the Rapid Member.

The spillway cuts through a portion of the Little Cedar Formation that has been structurally disrupted. The north wall and hill are cut by a northwest-southeast trending fault. A second structure runs perpendicular to this fault and is parallel to the axis of the spillway towards the north wall. This structural offset can be seen from Coralville Lake below the spillway.

While in the spillway area climbing the walls should be avoided to ensure the safety of the field trip participants below, and please keep sample collecting to a minimum.

MACBRIDE SPILLWAY

Location: NW¼NW¼SE¼SW¼ Section 29, T81N, R6W, Johnson Co.
Measured by: Bill J, Bunker and Orrin W. Plocher

UNIT 15. Argillaceous coralline calcilutite; unit contains solitary rugosans, *Hexagonaria*, echinoderm and brachiopod debris, 30 cm.

UNIT 14. Argillaceous skeletal calcilutite; unit contains brachiopod, bryozoan, and echinoderm debris, 50 cm.

UNIT 13. Argillaceous sparsely fossiliferous calcilutite; unit contains rare echinoderm, and brachiopod debris, unit has horizontal burrows, 44 cm.

UNIT 12. Argillaceous skeletal calcilutite; unit contains echinoderm, brachiopod, and bryozoan debris, 18 cm.

UNIT 11. Very argillaceous sparsely fossiliferous calcilutite; unit contains rare echinoderm debris, unit is burrowed, 75 cm.

UNIT 10. Skeletal calcilutite; unit is one massive bed, contains brachiopod, bryozoan, echinoderm debris, and *Hexagonaria*, 81 cm.

UNIT 9. Very argillaceous sparsely fossiliferous calcilutite; unit is laminated and recessive, unit contains rare brachiopod, bryozoan, and echinoderm debris, 58 cm.

UNIT 8. Argillaceous skeletal calcilutite; unit is massive bedded, contains echinoderm, brachiopod, and bryozoan, 56 cm.

UNIT 7. Argillaceous skeletal calcilutite; unit is recessive at top, contains echinoderm, brachiopod, bryozoan, and tentaculites, 93 cm.

UNIT 6. Argillaceous skeletal calcilutite; unit is recessive at top, contains *Hexagonaria*, brachiopod, bryozoan and echinoderm debris, 85 cm.

UNIT 5. Argillaceous skeletal calcilutite; unit is recessive at top, contains *Hexagonaria*, brachiopod, bryozoan and echinoderm debris, 49 cm.

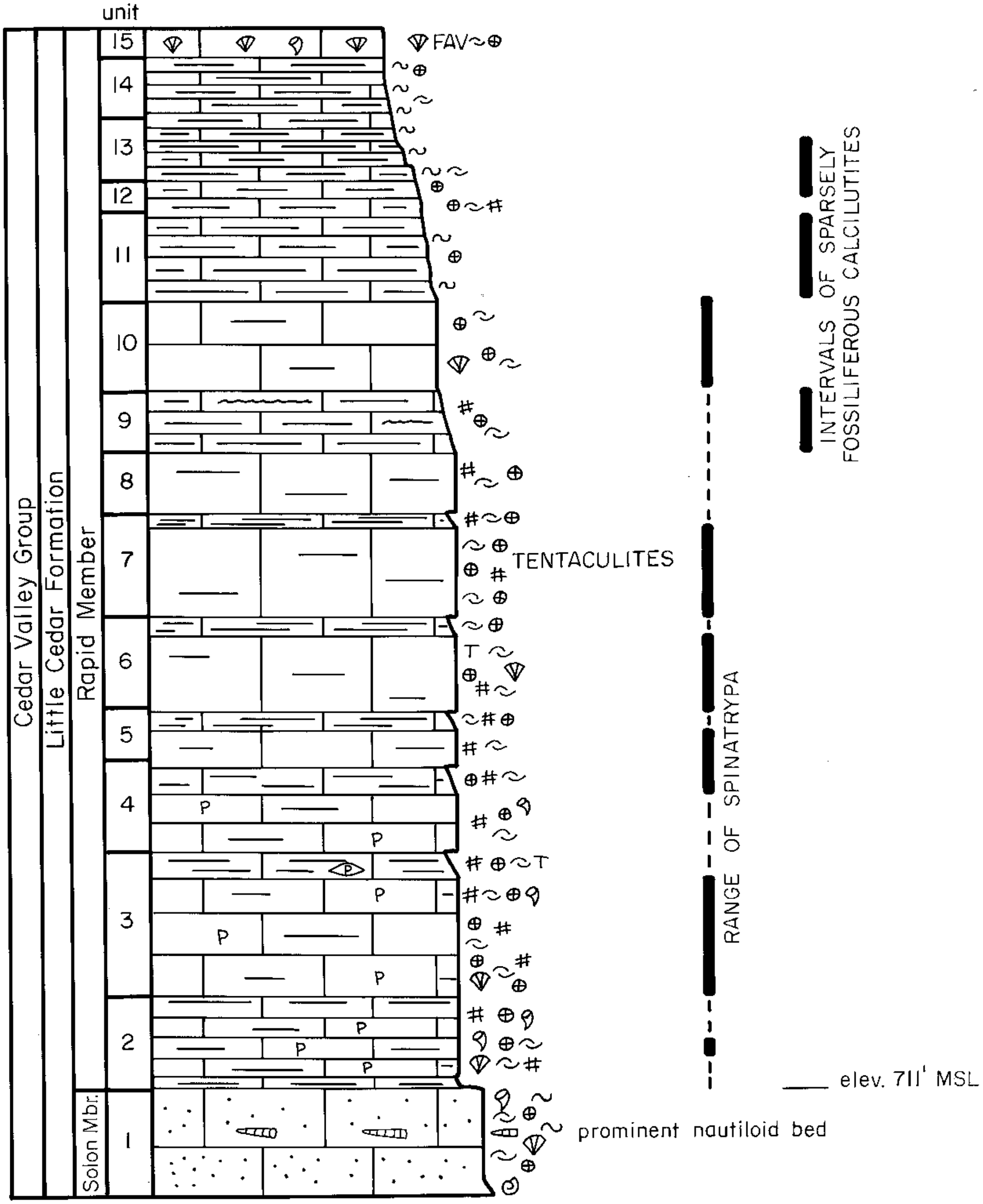
UNIT 4. Argillaceous skeletal calcilutite; unit contains calcarenite lens and is recessive at top, contains *Hexagonaria*, brachiopod, bryozoan and echinoderm debris, 78 cm.

UNIT 3. Skeletal calcilutite; unit contains calcarenite lens and is recessive at top, contains solitary coral, *Hexagonaria*, brachiopod, bryozoan and echinoderm debris, 130 cm.

UNIT 2. Skeletal calcilutite; unit contains calcarenite lens and has prominent shaley parting at base, contains calcarenite lens, solitary coral, *Hexagonaria*, brachiopod, bryozoan and echinoderm debris, 84 cm.

UNIT 1. Coralline stromatoporoid calcarenite; unit is massive bedded, contains brachiopod, bryozoan, echinoderm debris, *Asterobillingsa*, laminated and hemispherical stromatoporoids, 96 cm.

MacBride Spillway



STOP 2. Early Phase High Terrace of the Iowa River valley; Macbride Field Campus Picnic Area 4.
(discussion by Art Bettis; figures cited from Bettis, this guidebook).

The upper sixteen feet of the Early Phase High Terrace (EPHT) alluvial fill and the overlying Wisconsinan eolian deposits are exposed along the Coralville Lake shoreline at Picnic Area 4 in the Macbride Field Campus (Figure 1). The EPHT alluvium is contained within a valley cut into the underlying Devonian carbonates. On the upstream end of this exposure Devonian carbonates crop out high along the shoreline. Along this part of the outcrop oxidized and mottled Pre-Illinoian till overlies the Devonian rocks. Progressing in a downstream direction we encounter the eastern margin of the bedrock valley and the rock surface descends in elevation until it passes below average lake level. Along the margin of the bedrock valley the upper part of the till is truncated and colluvium grading laterally to fine-grained alluvium buries the till. The relationships among the Devonian rocks, till, and EPHT alluvium in this outcrop are very similar to those shown in the Sugar Bottom transect in Figure 2.

Deposits comprising the EPHT in this outcrop consist of an upward fining sequence grading from planar and shallow trough crossbedded medium and fine sand (with a few beds containing coarse sand) upward to loam and silty clay loam alluvium that exhibits no bedding structures. A shallow upward-fining trough fill is also present just above lake level on the west end of the outcrop. The upper fine-grained part of the EPHT alluvium is much finer-grained on the eastern (valley wall) side of the exposure than it is on the western (channel-ward) part of the exposure. This change in grainsize probably reflects more input of till-derived slope materials as well as a greater percentage of fine-grained overbank deposits along the valley wall margin of the EPHT than farther out in the valley.

This variation in grain size of the upper part of the EPHT alluvium strongly influences the morphology of the Sangamon Soil developed in the upper part of the EPHT alluvial fill. On the upstream part of the outcrop the Sangamon (or Late Sangamon) Soil is developed in Pre-Illinoian till. The soil descends onto colluvium then fine-grained alluvium of the EPHT and out onto loamy EPHT alluvium on the western part of the outcrop. Where it is developed on oxidized Pre-Illinoian till the paleosol is reddish brown colored and has a relatively thin, well expressed B horizon where secondary clay and iron moved from overlying soil horizons have accumulated. As it passes onto fine-grained EPHT alluvium along the margin of the bedrock valley the soil becomes much thicker and takes on a mottled gray color indicative of poor drainage conditions. In this position poor drainage is probably a function of the fine-grained character of the alluvial deposit, the landscape position at the base of the valley wall where water runs onto the site, and the possibility of seepage of shallow groundwater from the Devonian rocks along the valley wall. As the EPHT overbank alluvium grades to loam texture in the valley-ward direction the Sangamon Soil becomes well drained and has a reddish brown B horizon.

On the southern end of this outcrop the top of the EPHT deposits descend to lake level. In this area the EPHT deposits have been truncated by the west-trending tributary that boarders Picnic Area 4 on the south. The age of this truncation is discussed below.

Twenty-one feet of Wisconsinan loess buries the EPHT alluvial deposits and Sangamon Soil in this area. The loess thins toward the lake and along most of this outcrop the modern surface soil extends through both the Peoria Loess, and Roxana Silt equivalent and into the top of the Sangamon Soil. Because of this pedogenic mixing, the Roxana Silt equivalent is not recognizable along the outcrop.

Along the southern part of the outcrop, where the surface of the EPHT alluvium descends to lake level, the Peoria Loess is thicker and the Roxana Silt equivalent is not present. This stratigraphic sequence reflects truncation of the EPHT by a west-trending tributary during the late Wisconsinan. The cut surface and overlying loess sequence are stratigraphically correlative with the Late Phase High Terrace (LPHT).

The upper part of the Peoria Loess cap on the LPHT is visible to the west and northwest across the lake. Alluvial deposits of the LPHT are below lake level. Across the lake to the southwest the western wall of the bedrock valley rises above lake level and Devonian rocks are exposed along the shoreline.

STOP 3 - MEHAFFEY BRIDGE SECTION
Discussion is adapted and modified from Bunker & Witzke (1987)

In 1960, Congress authorized construction of Mehaffey Bridge to replace a structure which had been built prior to the turn of the century. It was during road excavations at the east end of the bridge that a unique combination of geological features was exposed. Immediately above and to the southeast of the roadcut, removal of approximately 50 ft (15.2 m) of drift and loess revealed a glacial pavement developed on the State Quarry Limestone, Lithograph City Formation. Here, a smooth knob of the State Quarry has been etched with parallel grooves and striations. The orientation of the grooves and striations indicate a NW to SE direction of glacial ice movement over the area. These furrows were gouged by rock fragments carried at the base of the ice mass as it inched across the rock surface. Beneath the glacially inscribed bedrock surface, spectacular exposures of richly fossiliferous limestones of the Cedar Valley Group outcrop along the roadcut. In 1969, 23 acres of hilly, partly wooded terrain, encompassing these geological features, which are of exceptional scientific and public interest, were dedicated as the Merrill A. Stainbrook Geologic Preserve.

Exposed in the roadcut of Stainbrook Preserve are upper beds of the Rapid Member of the Little Cedar Formation, the coral-stromatoporoid biostrome of the Cou Falls Member of the Coralville Formation, and skeletal calcarenites of the State Quarry Member of the Lithograph City Formation. Immediately to the north of the roadcut along the Coralville Lake front additional exposures of the lower Rapid are displayed. The two prominent biostromes of the Rapid (units 4 & 6), which are not exposed at the roadcut, can be traced to the north along the lake front.

Within the lower Rapid, beneath the biostromes, intervals of unfossiliferous to sparsely fossiliferous burrowed calcilutites occur. These beds differ from other argillaceous calcilutites of the Rapid by the paucity of skeletal grains and sparse faunal content. However, psilophyte plant remains, inarticulate brachiopods, bivalves, branchiopods, crustaceans, conularids, bryozoans, and trilobites have been noted (Zawistowski, 1971).

At the first reentrant to the north of Mehaffey Bridge an 18 ft (5.5 m) faulted interval occurs, which has displaced State Quarry calcarenites into juxaposition with the Rapid biostromes. To the south of Mehaffey Bridge the State Quarry channel incision is readily evident (see fig. 3 and discussion in Bunker & Witzke, this guidebook).

An isolated exposure of Pennsylvanian sandstone has been noted in the first reentrant to the south of the bridge. Isolated sandstone exposures can also be found to the south on the west side of the lake near the type section of the State Quarry.

Because this STOP is a *geologic preserve* <u>no</u> collecting of rock samples is permitted at the roadcut.

REFERENCES

Bunker, B.J., and Witzke, B.J., 1987, Cedar Valley Formation of the Coralville Lake area, Iowa: Geological Society of America, Centennial Field Guide - North-Central Section, p. 113-117.

Zawistowski, S.J., 1971, Biostromes in the Rapid Member of the Cedar Valley Limestone (Devonian) in east-central Iowa: unpublished M.S. thesis, University of Iowa, 120 p.

MEHAFFEY BRIDGE SECTION

(Modified from Bunker and Witzke, 1987)

Merrill A. Stainbrook Geological Preserve. (Encompasses units 7-13, as well as the overlying glacial pavement developed on the State Quarry Member, Lithograph City Fm; alignment of glacial striations range between 60° and 70° west of north, measured by Bill Bunker and Jean Prior, 1989) SW¼ SW¼ SW¼, Section 33, T81N, R6W; elevation of the bedrock surface at the top of the roadcut is approximately 748 ft (244 m) (sea level datum).

CEDAR VALLEY GROUP (Middle Devonian)

Lithograph City Formation

State Quarry Member

Unit 13. Skeletal calcilutite, scattered to rare brachiopods, lower contact slightly irregular; locally (far northeast exposure) an atrypid packstone is developed 8 to 20 cm above base of unit; *Variatrypa (Radiatrypa)* sp. cf. v. *(R.)* clarki, *Schizophoria*; 70 cm.

Unit 12. Skeletal calcarenite, brachiopod-rich, scattered crinoid debris; some small intraclasts; disconformable below (5 cm relief along exposure), locally with low-angle cross-beds; *Variatrypa* sp., *Cranaena*, spiriferids, rostroconchs, gastropods; 2 m.

Coralville Formation

Cou Falls Member

Unit 11. Biostrome, skeletal calcarenite; abundant stromatoporoids and corals, some overturned; intraclastic near base, irregular basal surface; *Idiostroma* (digitate stromatoporoids), hemispherical stromatoporoids, branching *Favosites*, pachyporid corals, horn corals, *Cranaena*; 70 cm.

Unit 10. Biostrome, skeletal calcarenite; abundant corals and stromatoporoids, many overturned; scattered brachiopods, *Desquamatia* common near base, *Psuedoatrypa* above, ?*Orthopleura* near top; encrusting and hemispherical stromatoporoids, *Favosites*, pachyporids, horn corals, *Hexagonaria*, *Conocardium*; irregular surface; 2.3 m.

Little Cedar Formation

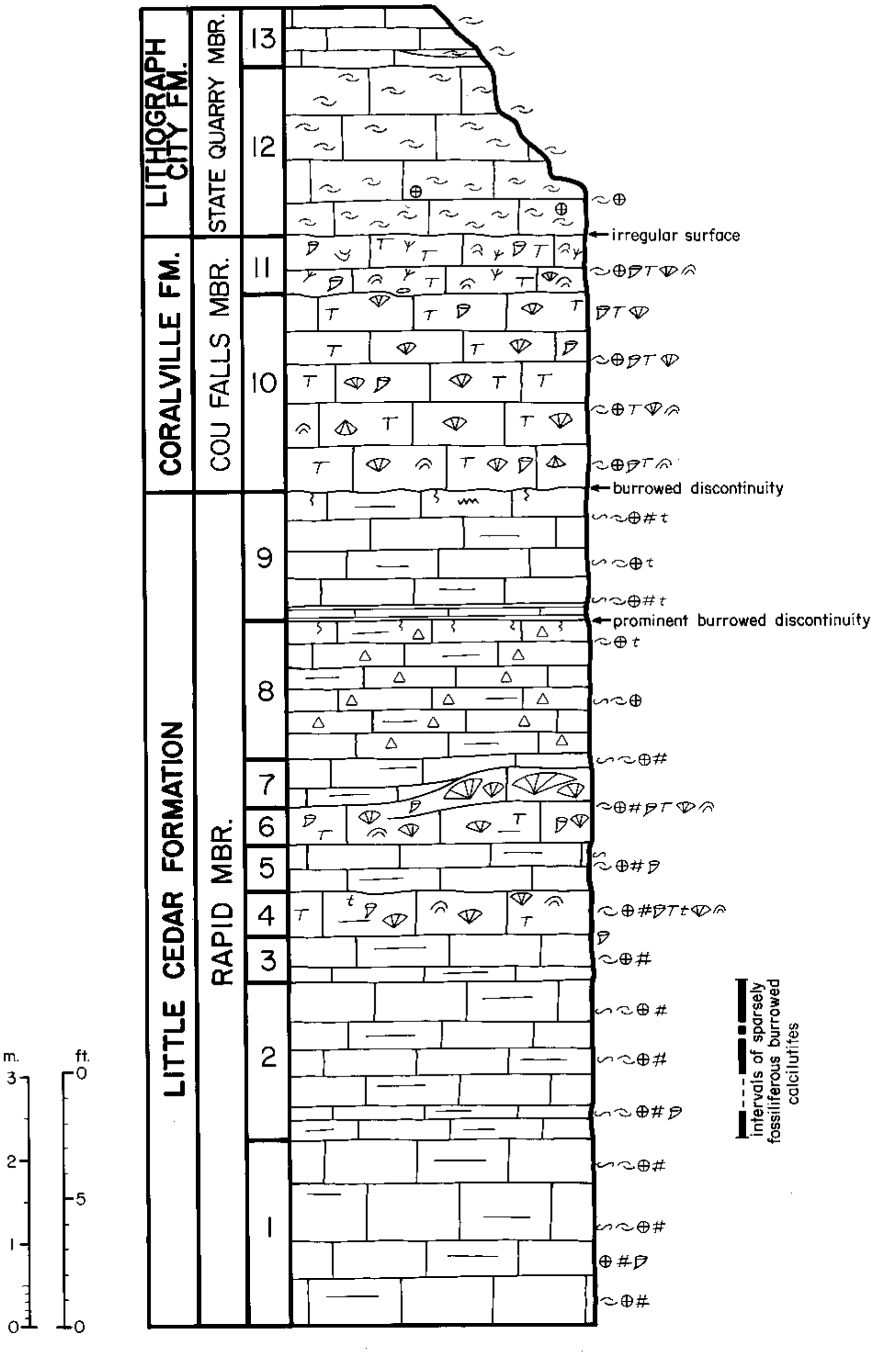
Rapid Member

Unit 9. Argillaceous skeletal calcilutite, some calcarenite lenses and stringers, burrowed; discontinuity surface at top (sharp break from calcilutite below to Coralville calcarenite above), vertical burrows infilled with Coralville lithologies extend downward locally to 20 cm; basal 11 to 15 cm with two prominent shale partings; abundant crinoid debris (including *Megistrocrinus*), bryozoans (including *Sulcoretopora*), scattered pachyporid corals, large *Desquamatia waterlooensis*, *Orthospirifer*, *Tylothyris*, *Cranaena* (upper part), *Strophodonta*, *Schizophoria*, other brachiopods; 1.5 m.

Unit 8. Argillaceous skeletal calcilutite to calcarenite, burrowed; prominent discontinuity surface at top with abundant vertical burrows to 10 cm; scattered to abundant nodular chert (smooth to chalky), nodules 1 to 30 cm; glauconitic to very glauconitic in upper part; abundant crinoid debris, scattered small to large brachiopods including *Orthospirifer* and ?*Desquamatia*; pachyporid corals near top; 1.7 m.

Unit 7. Argillaceous skeletal calcilutite with lenses or stringers of calcarenite; oversteps upper surface of underlying biostrome; shaley to very argillaceous at top; small *Favosites* and horn corals near base; crinoid debris (including *Megistocrinus*), bryozoans, *Orthospirifer*, *Tylothyris*, *Schizophoria*, *Pseudoatrypa*, *Athyris*, *Cranaena*, *Pentamerella*; 27 to 70 cm.

MEHAFFEY BRIDGE SECTION
Merrill A. Stainbrook Geologic Preserve
SW SW SW Sec. 33, T81N, R6W; elevation 748' (sld.)



Unit 6. Biostrome, slightly argillaceous skeletal calcilutite to calcarenite; shaley parting at top; biostrome varies laterally, where thickest includes massive accumulations of *Hexagonaria*; crinoid debris, fenestellid bryozoans, horn corals, *Favosites*, alveolitids, *Hexagonaria*, encrusting stromatoporoids, *Pseudoatrypa*, *Tylothyris*, *Strophodonta*, *Cranaena*, *Gypidula*, *Pentamerella*; 40 to 85 cm.

Unit 5. Argillaceous skeletal calcilutite, burrowed, shaley at top; crinoid debris (including *Megistocrinus*), bryozoans (including fenestellids and cystodictyonids), horn corals at top, *Orthospirifer*, *Pseudoatrypa*, *Strophodonta*, *Schizophoria*; 35 to 70 cm.

Unit 4. Biostrome, argillaceous skeletal calcilutite to calcarenite; *Favosites*, alveolitids, pachyporids near top, *Hexagonaria*, horn corals, hemispherical stromatoporoids, crinoid debris, *Orthospirifer*, *Pseudoatrypa*; 50 cm.

Unit 3. Argillaceous skeletal calcilutite to calcarenite at top; crinoid debris, bryozoans (including fenestellids), *Orthospirifer*, *Pseudoatrypa*, *Schizophoria*, horn corals at top; 53 cm.

Unit 2. Sparsely fossiliferous to unfossiliferous argillaceous calcilutite, contains lenses or stringers or argillaceous skeletal calcilutite to calcarenite; extensively burrow-mottled throughout; fossiliferous horizons include crinoid debris (including *Megistocrinus*), bryozoans (including fenestellids), strophomenids, *Orthospirifer*, *Tylothyris*, *Pseudoatrypa*, *Schizophoria*, *Retichonetes* (upper part); lower part locally includes horn corals and *Hexagonaria* (30 cm); 1.9 m.

Unit 1. Argillaceous skeletal calcilutite to calarenite, burrowed; crinoid debris (including *Megistocrinus*), bryozoans (including fenestellids and cystodictyonids), horn corals in lower part, *Phacops*, *Spinatrypa bellula*, *Pseudoatrypa*, *Orthospirifer*, *Tylothyris*, *Schizophoria*; 2.2 m.

REFERENCE

Bunker, B.J., and Witzke, B.J., 1987, Cedar Valley Formation of the Coralville Lake area, Iowa: Geological Society of America Centennial Field Guide - North-Central Section, p. 113-117.

STOP 4 - MID-RIVER MARINA QUARRY

Discussion by Orrin W. Plocher, Bill J. Bunker, and Brian J. Witzke.

Stops 4 and 5 are in two of four remaining abandoned quarries near where present day Highway 965 crosses the Iowa River in northern Johnson County, Iowa. Two additional quarries were reportedly filled during the construction of present day Interstate 380. The dates of operation of these quarries is uncertain but their close proximity to the highways that cross the river suggest that stone from these quarries was used in their construction and possibly for local buildings. The quarry closest to the Mid-River Marina (Mid-River Marina Quarry, STOP 4) is the largest of the remaining quarries. This quarry exposes the upper Rapid Member of the Little Cedar Formation and the Cou Falls and Iowa City members of the Coralville Formation. This quarry is notable in that it was one of the first localities where the "Curtis Bridge" grainstones were recognized (Bunker and Plocher, 1987), and later became the type section for the Cou Falls Member, Coralville Formation (Witzke et al., 1988). Merrill A. Stainbrook visited many of these quarries in the 1920's and 30's, and described a unit in the upper Rapid with a "granitoid texture" (unpublishes field notes). These "granitoid" rocks are informally referred to as the "Curtis Bridge" grainstones (see STOP 5). In many instances, the grainstone is very coarse grained and weathers to a light red giving a granite-like appearance. Grainstone units within the quarry are variable and in some positions has a crossbedded character (Fig A). Beneath the grainstone beds are packstone units with conspicuous chert nodules. Many articulated echinoderms have been recovered from within calcilutite partings between the grainstone units, including crinoids, cystoids, and echinoids.

The contact between the upper Rapid Member, Little Cedar Formation, and the overlying Cou Falls Member, Coralville Formation, is a sharp burrowed discontinuity surface. Lithic-clasts of Rapid lithologies are included within the basal few inches of the Cou Falls coralline-stromatoporoid abraded packstones. Overlying the Cou Falls Member are strata of the Iowa City Member which includes pelleted intraclastic units, gastropod oncolite, and lithographic birdseye lithologies.

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.

REFERENCE

Witzke, B.J., Bunker, B.J., and Rogers, F.S., 1988, Eifelian through Lower Frasnian stratigraphy and deposition in the Iowa area, Central Midcontinent, U.S.A.: *in* McMillan, N.J., Embry, A.F., and Glass, D.J. (eds.), Devonian of the World, Canadian Society of Petroleum Geologists, Memoir 14, Volume I: Regional Syntheses, p. 221-250.

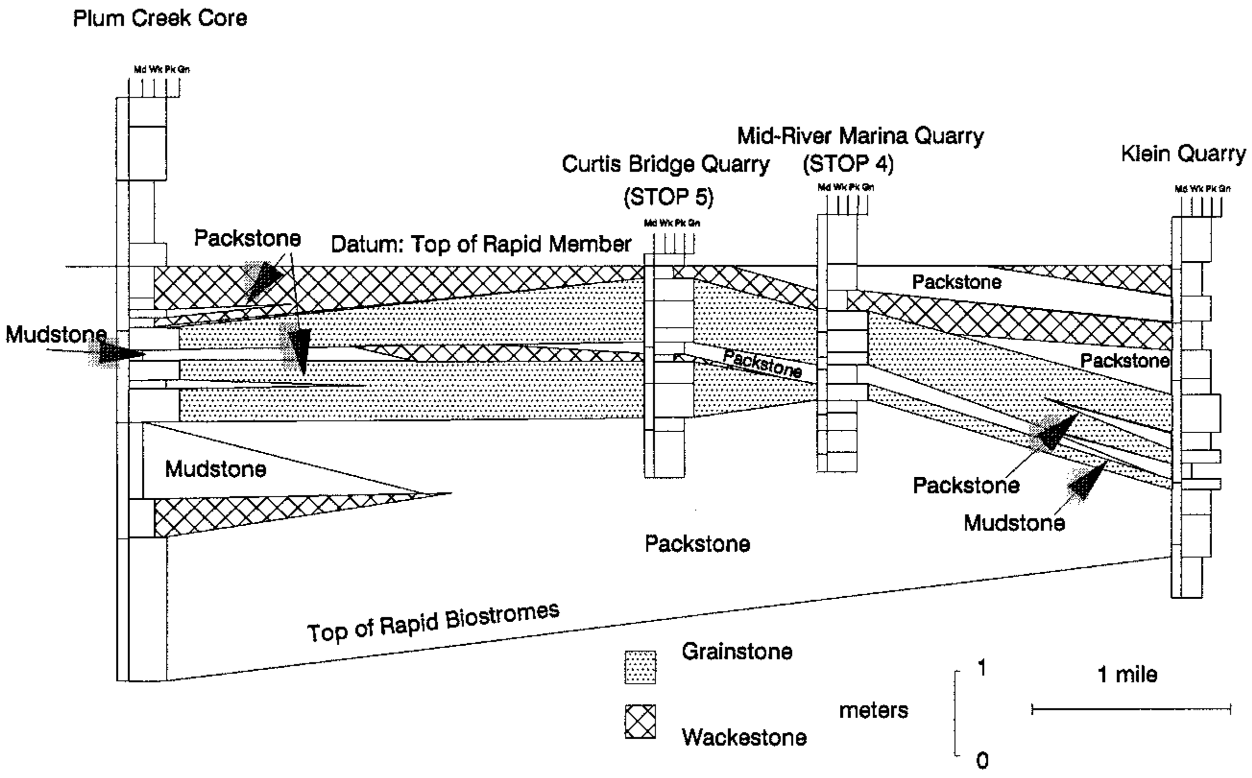


Figure A. Local lithic cross-section through the grainstone facies in Johnson County, Iowa.

MID RIVER MARINA QUARRY

Type section Cou Falls Member
NE¼NW¼NE¼SE¼ Section 27, T81N, R7W, Johnson Co.
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 briostrome 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 volume; *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.

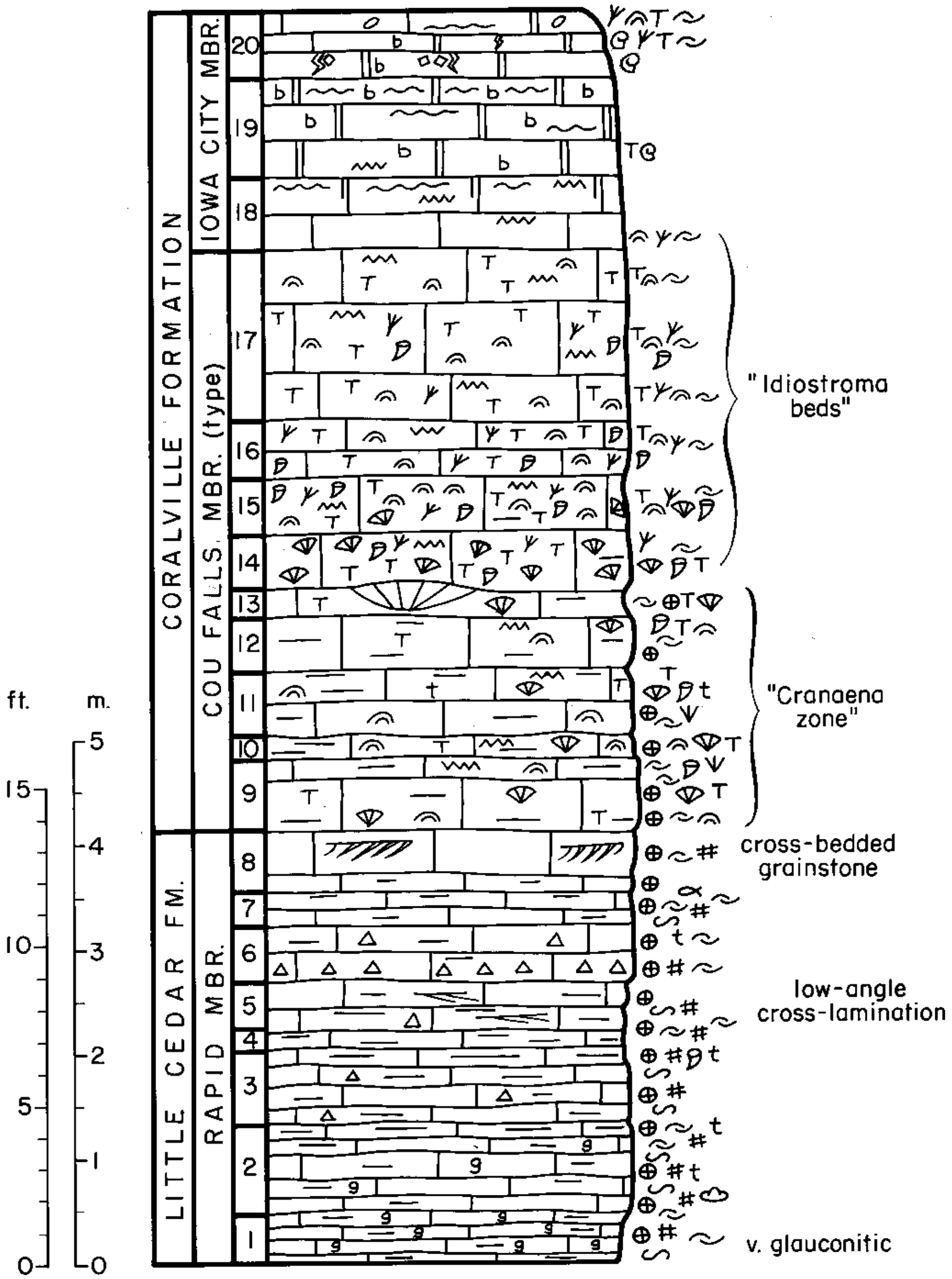
Unit 7. Ls., interbedded argillaceous calcilutite and calcarenite, dominated by packstone-grainstone, very crinoidal, thinly-bedded shaley interval forms re-entrant at top, calcilutite-filled horizontal burrows present; brachiopods include *Desquamatia, Tylothyris, Orthospirifer, Cyrtina*; small bryozoans, 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, brachioppods (*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.

Mid River Marina Quarry
type section Cou Falls Mbr.
NE NW NE SE sec. 27, T81N, R7W, Johnson Co.



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.

STOP 5 - CURTIS BRIDGE QUARRY

Discussion by Orrin W. Plocher.

Three generations of north-south parallel highways, following approximately the 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, 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. The grainstone at this locality achieves it's greatest thickness and is the only known location where well developed high-angle crossbeds can be observed. These two facts distinguish the grainstone at Curtis Bridge from other locations where it has been recognized (Fig. A). 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 (see discussion by Plocher & Ludvigson, this guidebook).

The contact between the Little Cedar and Coralville formations is a distinct burrowed discontinuity 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. Many large colonial corals can be found on weathered bedding plane surfaces in the upper part of the quarry.

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Bunker, B.J., and Plocher, O.W., 1987, Devonian stratigraphic framework of the Coralville Lake area, Phase 2: unpublished report for the U.S. Army Corps of Engineers, Rock Island, 18 p.

Plocher O.W., 1987, A crossbedded grainstone unit in the upper Rapid Member, Cedar Valley Formation, Middle Devonian of Johnson County, Iowa (abs.): Proceedings of the Iowa Academy of Science v. 94, Program Abstracts, 99th session, Abs. No. 144.

Witzke, B.J., Bunker, B.J., and Rogers, F.S., 1988, Eifelian through Lower Frasnian stratigraphy and deposition in the Iowa area, Central Midcontinent, U.S.A.: *in* McMillan, N.J., Embry, A.F., and Glass, D.J. (eds.), Devonian of the World, Canadian Society of Petroleum Geologists, Memoir 14, Volume I: Regional Syntheses, p. 221-250.

CURTIS BRIDGE QUARRY

NW¼NE¼SW¼SE¼ 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.

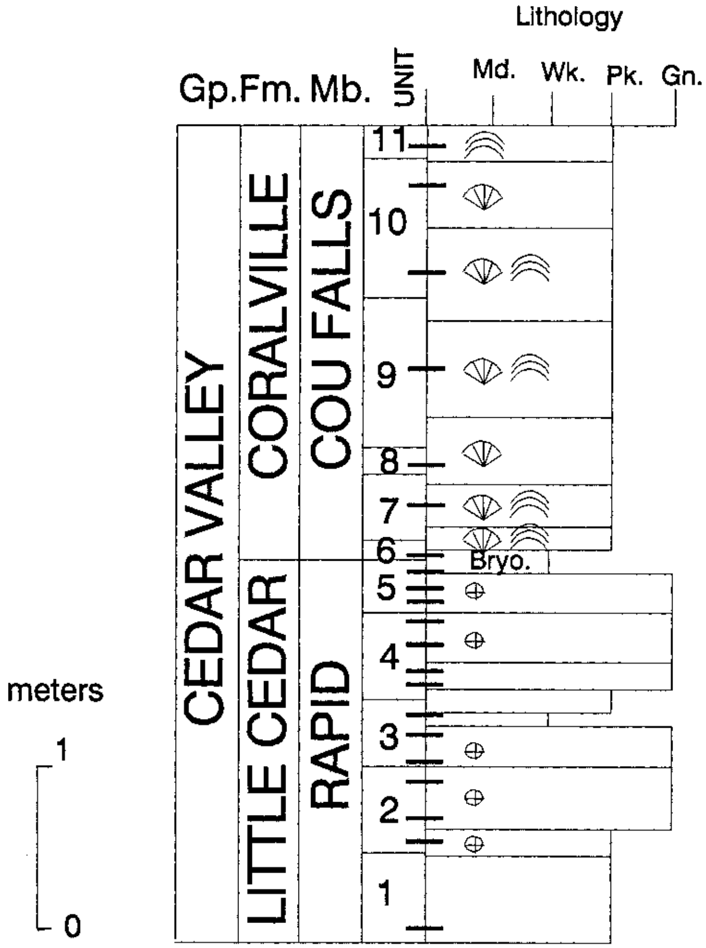
Unit 3. Burrowed medium- to fine-grained echinoderm calcarenite; planar cross-beds to wavy bedded, scattered brachiopods; 40 cm.

Unit 2. Medium- to coarse-grained echinoderm calcarenite, wavy bedded, whole brachiopods, limonite replacement of some grains; 55 cm.

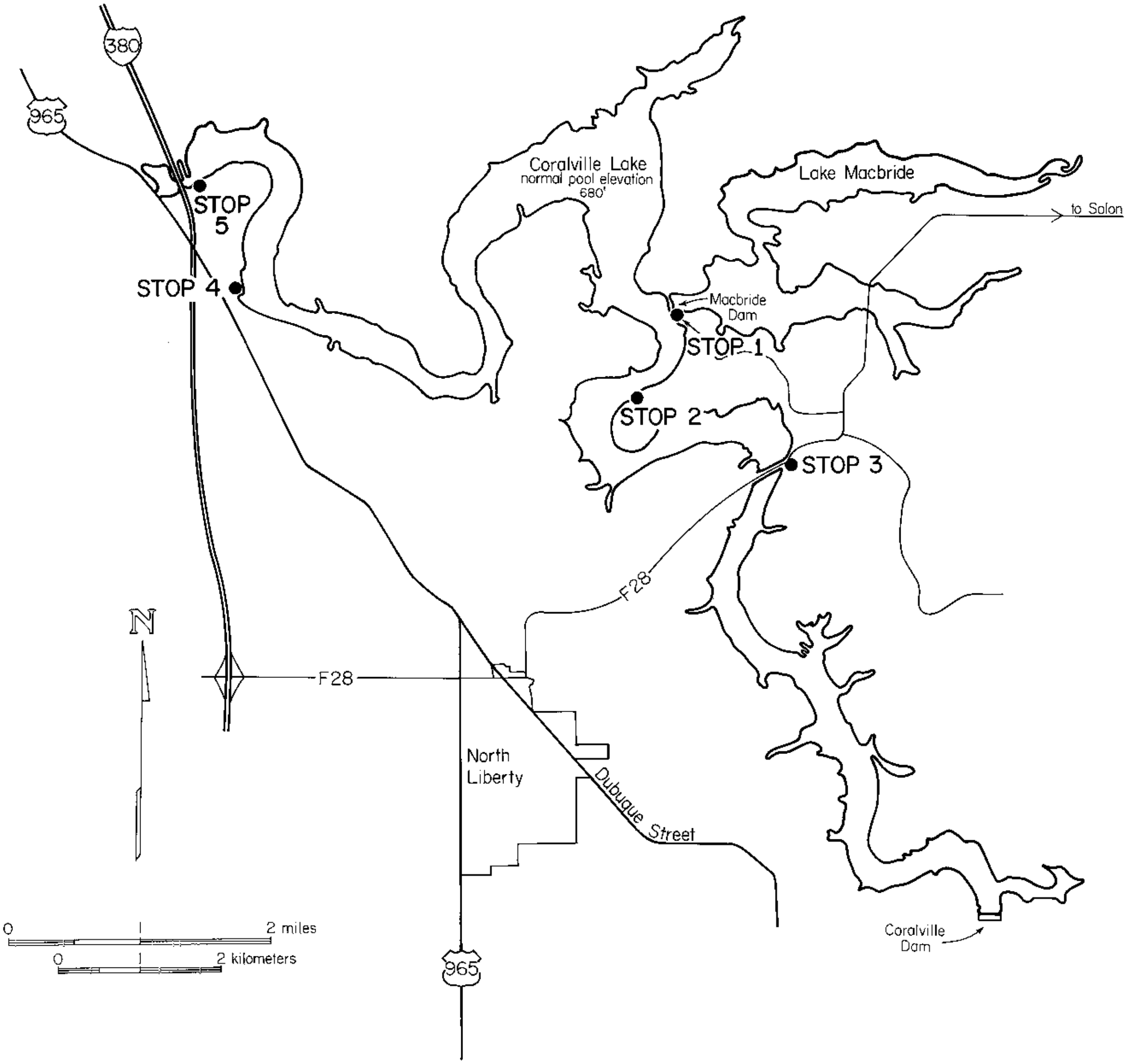
Unit 1. Laminated sparsely fossiliferous calcilutite; scattered fine-grained calcarenite, small scale horizontal and vertical burrows present; 55 cm.

CURTIS BRIDGE QUARRY

Location: NW, NE, SW, SE, SECTION 22, T81N, R7W



Geological Society of Iowa
%Iowa Department of Natural Resources
Geological Survey Bureau
123 North Capitol Street
Iowa City, Iowa 52242



Location map of field trip stops