SILURIAN STRATIGRAPHY OF EASTERN LINN AND WESTERN JONES COUNTIES, IOWA

A field trip investigation of carbonate mound and inter-mound facies of the Scotch Grove (new) and Gower Formations

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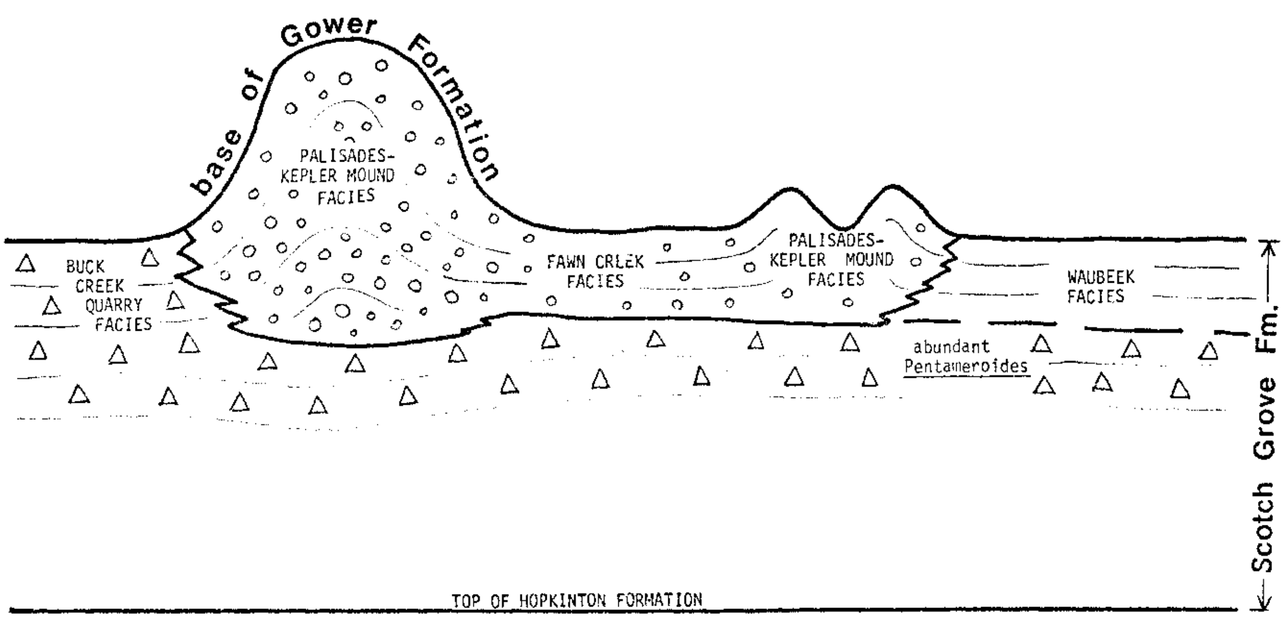

GUIDEBOOK 35

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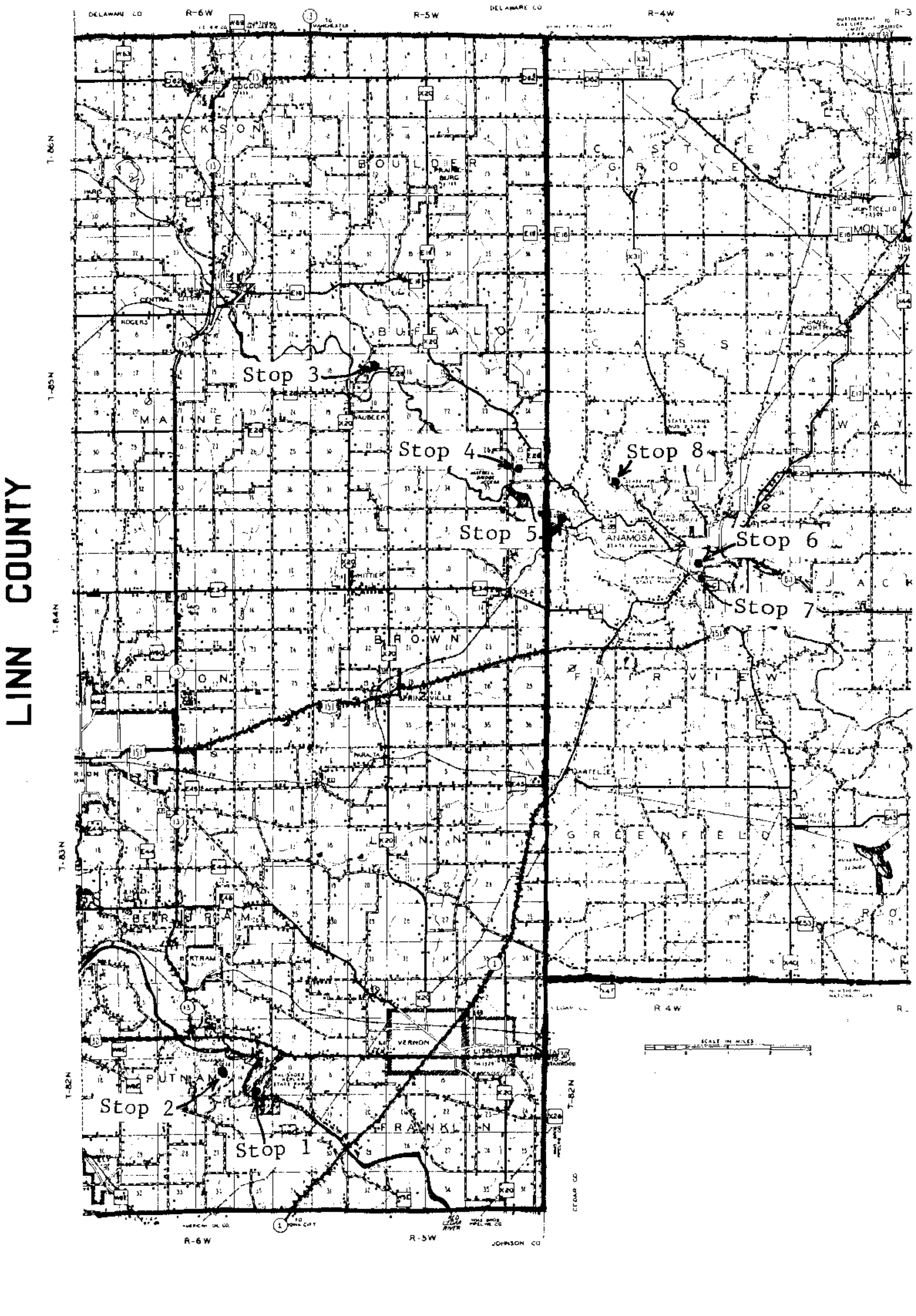
LINN COUNTY
JONES COUNTY
Stop 1
Stop 2
Stop 3
Stop 4
Stop 5
Stop 6
Stop 7
Stop 8
R-6W
R-5W
R-4W
ANAMOSA
MT. VERNON
LISBON
SPRINGVILLE

ABSTRACT

A new formation, the Scotch Grove Fm., is introduced to occupy the position above the top of the Hopkinton Formation (as originally defined by Calvin) and below the base of the first laminated dolomites of the Gower Formation. Rocks included in the Scotch Grove Formation of this report were variably included within the Hopkinton or Gower Formations by previous workers. A diversity of carbonate facies in the upper Scotch Grove Formation will be examined during the field trip, and these facies are given geographic names to facilitate discussion. Three flat-lying facies in the upper Scotch Grove Formation (Buck Creek Quarry, Waubeek, and Fawn Creek) are distinguished by the presence or absence of chert and by general skeletal content. These facies are laterally equivalent to crinoidal carbonate buildups termed the Palisades-Kepler Mound Facies, and all previous workers have included these buildups within the "LeClaire Facies" of the "Gower Formation". However, the Gower, as originally defined, should not include strata that are not laterally equivalent to laminated Anamosa dolomites. The Gower Formation includes two general facies in the field trip area: 1) laminated dolomites of the Anamosa Facies, and 2) brachiopod-rich carbonate buildups of the Brady Facies. The Scotch Grove Formation was deposited in a situation of generally open marine circulation. Regression of the Silurian sea created a restricted embayment in east-central Iowa in which Gower deposition occurred. Subtidal laminated organic mats of the Anamosa Facies were probably deposited in hypersaline waters beneath a halocline.

INTRODUCTION

Although the Silurian rocks of Iowa have been the subject of geologic studies for over 120 years, the basic lithostratigraphy of the entire Silurian sequence has never been adequately defined. Previous studies (especially Rowser, 1932 and Hinman, 1963) have outlined the history of stratigraphic nomenclature in the Iowa Silurian, and most of this history need not be reiterated herein. Hall (in Hall and Whitney, 1858) first named the "limestone of Leclaire rapids" after exposures of hard dolomite, often with rugose corals and abundant small brachiopod molds, at the town of LeClaire, Scott County. He noted that these strata occur as both horizontal and "folded" beds. By the early 1890s other workers had expanded the definition of the "LeClaire Limestone" to include three different rock types: 1) hard dolomite often with abundant small brachiopod molds, 2) porous, crinoidal, coral-bearing dolomite, and 3) laminated dolomite.

Norton (1895) introduced the term "Mt. Vernon beds" for the sequence of laminated dolomites exposed in quarries near Mt. Vernon, Linn County, and the laminated rocks at LeClaire, Stone City, and the Upper Palisades (Palisades-Kepler State Park) were correlated with the Mt. Vernon beds. Norton (1895, p. 134, 135) stated that "no conclusive proof has yet been found that the Mt. Vernon beds were formed simultaneously with the reef rock" (i.e., LeClaire), and the Mt. Vernon beds probably "represent a somewhat later stage of Silurian sedimentation" than the LeClaire beds. Calvin (1896) defined the "LeClaire Stage" in stratigraphic position above the "Delaware Stage" (later named Hopkinton in 1906), and the LeClaire is described as a massive, chert-free, rugose coral-bearing or small brachiopod-moldic, crystalline dolomite. The upper surface of the LeClaire is noted by Calvin (1896, p 51) to be "exceedingly undulatory" and in places obliquely-bedded, and the LeClaire "varies locally in thickness." Calvin (1896) did not utilize Norton's term, Mt. Vernon beds, but, instead, proposed a new stratigraphic term, the "Anamosa Stage". Calvin chose the quarries at Stone City (western Jones Co.) as the type locality, but, in fact, "the beds of this stage do not occur at [the town of] Anamosa" (p. 57). The term "Anamosa Stage" was formally proposed because this type of laminated rock was regionally marketed from railheads at Anamosa as "Anamosa stone", and the Stone City quarries were "generally known as the Anamosa quarries" (p. 56). Calvin also referred the laminated dolomites at LeClaire, Mt. Vernon, and Cedar Valley to the Anamosa Stage. Calvin (1896, p. 50) described rocks of the LeClaire Stage stratigraphically beneath rocks of the Anamosa Stage.

Norton (1899, p. 423) reversed his opinion on the relationships between the LeClaire and Anamosa beds: "These subdivisions have been ranked hitherto as distinct stages, but the evidence at hand does not seem to warrant any chronological separation. The terms LeClaire and Anamosa will therefore be used merely as convenient designations of different varieties of rocks of the same stage." Norton (1899) then porposed the term Gower Stage to include both Anamosa and LeClaire lithologies, and the Bealer Quarries at Cedar Valley, Gower Township, Cedar County were chosen as the type locality. "In Scott county alternations along the same horizons between the LeClaire and Anamosa are frequent; the intermediate lithologic forms between them are numerous . . . so that it becomes impracticable to maintain a formation distinction corresponding to the lithologic one" (p. 430). These observations in Scott County have not been disputed by subsequent workers and are essentially verified by my own research. However, the term LeClaire, as previously noted, had taken on a variety of meanings for various rock types in other counties in Iowa, and the assumption that <u>all</u> rocks classified as LeClaire throughout Iowa were deposited synchronously with laminated Anamosa sediments has certainly never been demonstrated. This study proposes that much of the rock previously included in the "LeClaire" lies below the Anamosa beds and represents a previously unnamed stratigraphic interval. Norton (1901, p. 308) proposed that the anomalous "folding" and "mounds" noted within the Gower were formed by "in situ accumulation of corals, crinoids, and molluscous shells" and "calcareous muds" into "huge mounds and ridges on the bottom of the shallow Silurian sea." Norton, therefore, introduced the idea that the mounds and oblique bedding in the Gower are related to bioherms or "reefs" that grew as skeletal debris and carbonate mud built up on the sea bottom.

Two theses by Rowser (1929, 1932) on the Gower Formation in eastern Iowa are significant in that the faunas were described or listed for the first time, and an attempt to define the Gower-Hopkinton boundary was made. Rowser (1929, p. 14) stated that the LeClaire and Anamosa "phases" were "deposited at the same time," and "'reef' and 'interreef' will be used to denote the two facies of the Gower" (Rowser, 1932, p. 16). He noted (1929, p. 39) that echinoderm debris is the "most important" skeletal constituent of the "LeClaire" facies. At the top of the interval now known as the "Favosites Beds" (see Johnson, 1975), Rowser (1932, p. 36, 37) defined the Gower-Hopkinton contact. As will be shown, the lower part of the "Gower," as defined by Rowser (1932), is not equivalent to any portion of the Anamosa facies but lies stratigraphically below rocks here included in the Gower.

In the 1960s and early 1970s, the Gower Dolomite was the subject of studies by four independent workers, who, reminiscent of the previous century, put forward widely divergent opinions regarding the relationships of the Anamosa and LeClaire beds. Hinman's (1963, 1968) studies of the Gower Dolomite focused on five localities in Linn and Cedar Counties. He recognized that the "LeClaire" beds often form bioherms or reefs, but he also noted that muck of the "LeClaire is represented by flat-lying beds" (Hinman, 1963, p. 24). Hinman included all dipping "flank beds" within the "LeClaire" facies, and he concluded that the Anamosa is "the flat-lying inter-reef facies" that ultimately overlapped the reefs (ibid., p. 180). Smith (1967) was the first to describe the thin-section petrography of the Gower, and, like Hinman, concluded that the Anamosa is the inter-reef facies deposited contemporaneously with the reefal "LeClaire". However, unlike Hinman, Smith did not recognize any non-reefal "LeClaire" deposits. Philcox (1970, 1972) presented a radically different picture of Gower deposition, suggesting that the LeClaire/Anamosa subdivision of the Gower is inadequate to explain the complex facies relationships that he observed. Philcox (1970) recognized two phases of Gower reef growth: the first is characterized by skeletal, crinoid- and coelenterate-rich "LeClaire" facies and the second by a laminated to skeletal (dominated by amplexid corals and rhynchonellid brachiopods) "Brady Facies." He further suggested that the Anamosa Facies is, in part, equivalent to the Brady Facies and that the Anamosa was deposited at a later time than the crinoidal "LeClaire" reefs (Philcox, 1972). Henry (1972) reached similar conclusions about the Anamosa/LeClaire relationships noting that "field evidence indicates that the Anamosa facies sediments were deposited later than most of the LeClaire buildups" (p. 17) and that "much of the rock that has been called LeClaire is present both in buildups and in flat-lying beds" (p. 13). Henry concentrated his study in the Stone City area, the type region for the Anamosa beds. He also documented the petrography of the Anamosa beds and offered several possible interpretations for the depositional environments of the thick sequence of laminated dolomites at Stone City.

What is the definition of the Gower Dolomite? The Gower includes laminated dolomites at the type locality, but it has come to include additional rock types, especially flat-bedded and biohermal crinoid- and coral-rich rocks. Should the Gower only include the laminated Anamosa Facies and its contemporaneous biohermal facies as Norton originally defined it? Or should it also include the bedded crinoidal dolomites and crinoid/coral-rich biohermal buildups that may not be contemporaneous with the laminated Anamosa Facies? With the exception of Philcox's and Johnson's "Hopkinton" bioherms, all modern workers on the Iowa Silurian have placed any biohermal rock within the Gower Dolomite irrespective of whether these rocks satisfy Norton's original definition of contempor—

aneity with the Anamosa Facies. Norton himself included rocks within the Gower that do not satisfy this original definition. What are the exact relationships of the "LeClaire" and Anamosa Facies? Are all reefal "LeClaire" beds contemporaneous with Anamosa beds? Philcox (1970, 1972) and Henry (1972) suggest not. If they are correct, what variety of intereef facies are present, and can these facies be logically included within the Gower Dolomite? These questions will be addressed during the course of the field trip.

Most previous workers have assumed that the Hopkinton Dolomite underlies the Gower Dolomite, although the nature of this contact has received little attention in the literature. Unfortunately, the top of the Hopkinton Dolomite has been defined by previous workers at more than one position, and the stratigraphic position of the upper boundary needs to be clarified. Wilson's (1895) report on the Silurian stratigraphy of northeastern Iowa was utilized by Calvin (1896) to define the "Delaware Stage" of the Silurian. Calvin (1896, p. 49) defined the Delaware Stage to include "divisions one to four of Professor Wilson's paper." Division four was termed the "upper Coralline beds" lying in stratigraphic position above division three, the "Pentamerus beds". Utilizing the stratigraphic terminology of Johnson (1975), the top of Wilson's fourth division would correspond to the top of the "Favosites Beds." Because the term Delaware was pre-occupied for a Devonian rock unit in Ohio, Calvin introduced the "Hopkinton Stage" as a replacement in 1906. Later workers (e.g. Boucot, 1964; Berry and Boucot, 1970; Johnson, 1975; Witzke, 1978) included a thick stratigraphic interval above Wilson's fourth division within the Hopkinton Dolomite, although, for reasons outlined later, Calvin's original definition of the upper boundary of the Hopkinton may be the most practical. The interval above Wilson's fourth division, but below the first laminated Gower dolomites, includes Pentameroides-bearing cherty dolomites (Pentameroides is a large pentamerid brachiopod). Earlier inclusion of Pentameroides-bearing beds within the Hopkinton Dolomite by Calvin may have influenced the stratigraphic placement of these beds by later workers. The inclusion of Pentameroides-bearing beds within the Hopkinton by Calvin, however, resulted from the fact that "Calvin equated the occurrence of Pentamerus oblongus from his Pentamerus Beds with that of Pentameroides subrectus from younger strata" (Johnson, 1975, p. 132). Johnson (1975, p. 133) further explained: "The error caused Calvin to exclude several distinctive beds from his stratigraphy. He was perplexed that faunas succeeding what he though to be the same Pentamerus beds at localities not far separated were so different. This factor Calvin attributed to the inconstancy of life on the Silurian sea bottom." Calvin's error in fossil identification had the effect of elevating the top of the Hopkinton to include rocks not originally included within his definition of the Hopkinton (which was placed at the top of Wilson's fourth division=Favosites Beds). The "upper Hopkinton" beds, i.e., strata above the Favosites Beds, had previously been referred to the LeClaire Dolomite by some workers (e.g., Whitney in Hall and Whitney, 1858; Rowser, 1929).

Johnson's extensive studies (1975, 1977a, 1977b, 1979, 1980) have greatly clarified much of the stratigraphy, paleontology, and paleoecology of the Lower Silurian in Iowa. He also included a sequence of strata

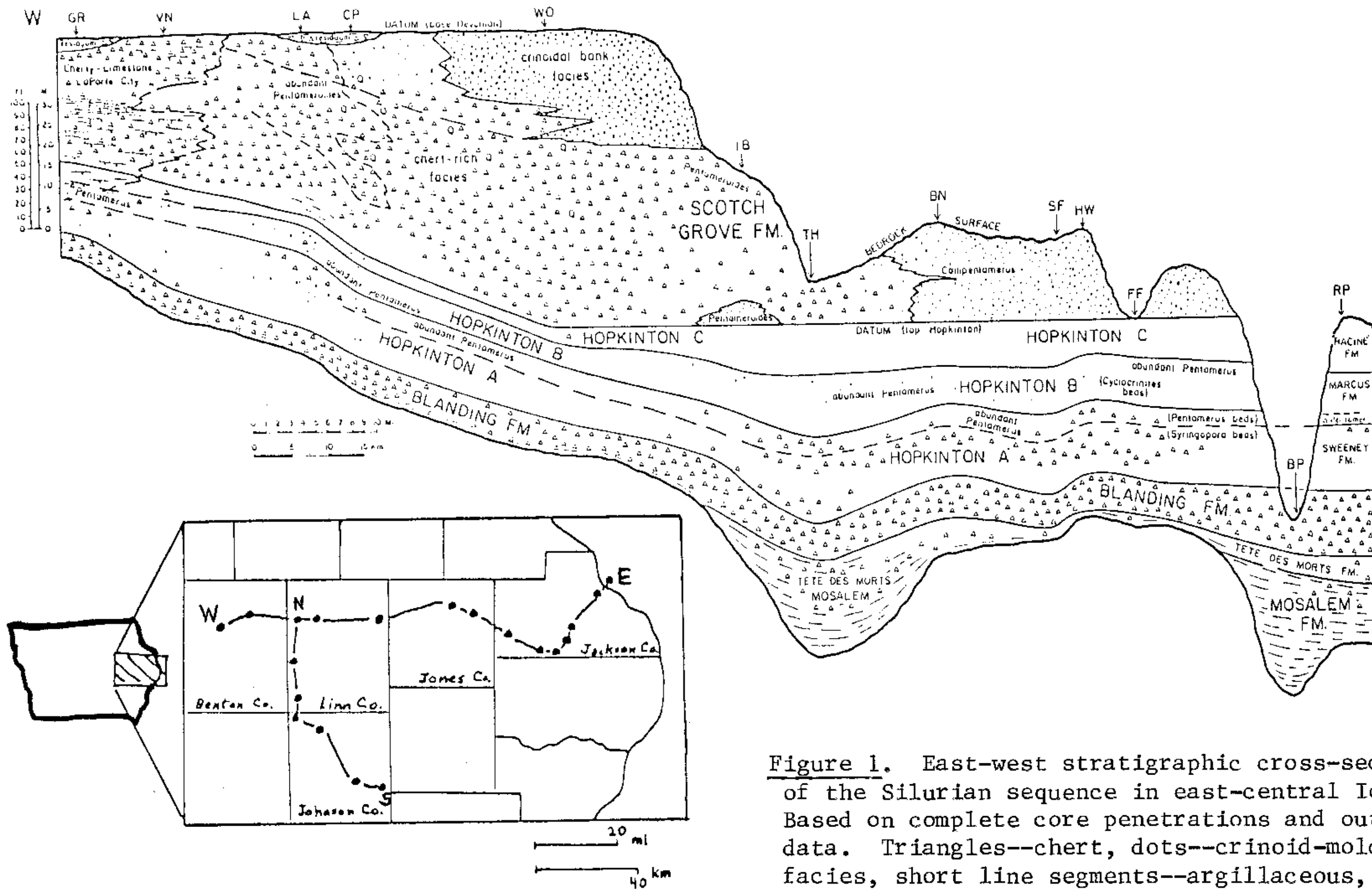

Figure 1. East-west stratigraphic cross-section of the Silurian sequence in east-central Iowa. Based on complete core penetrations and outcrop data. Triangles--chert, dots--crinoid-moldic facies, short line segments--argillaceous, Q--quartz-lined vugs. The cherty limestone sequence in Benton Co., the LaPorte City Fm., is laterally equivalent to dolomites of the Scotch Grove and Hopkinton Formations. Note eastward thickening of individual stratigraphic units.

above the "*Favosites* Beds" within the upper portion of the Hopkinton Dolomite, in ascending order, the "Bioherm Beds," "*Cyrtia* Beds," and "*Pentameroides* Beds." Johnson (1980) placed the Hopkinton-Gower contact at the top of his "*Pentameroides* Beds," although the nature of this contact was not defined. Witzke (1976, 1978) largely accepted Johnson's subdivisions of the Hopkinton, and the top of the Hopkinton was placed at the top of the *Pentameroides*- and/or *Callipentamerus*-bearing beds with the overlying "Gower" rocks consisting of porous crinoidal dolomites. Witzke (1980) later outlined a westward thinning of the sub-"*Favosites* Beds" portion of the Hopkinton Dolomite between the outcrop belt in Jackson-Dubuque Counties and the subsurface of Linn-Johnson Counties, and, for the first time, the "upper Hopkinton Fm. (post-*Favosites* beds)" was noted to be partly a facies equivalent of "porous, crinoidal beds" that had previously been "assigned to the Gower Fm."

The historical development of Silurian stratigraphic nomenclature in Iowa presents some interesting dilemmas that need resolution. Where should the top of the Hopkinton be drawn? Should it be placed at the top of Johnson's (1975) *Favosites* Beds where Calvin apparently originally defined it? Or should the Hopkinton also include the younger Silurian strata that Calvin incorrectly correlated with the *Pentamerus* Beds of the Hopkinton? Most modern workers have affirmed the latter choice and elevated the upper boundary of the Hopkinton. A formational boundary should be recognizable over its geographic extent, and recent studies suggest that drawing a formational boundary at the top of the *Pentameroides*-bearing beds is not advisable.

Subsurface studies utilizing complete core penetrations of the Silurian interval in eastern Iowa have greatly clarified many stratigraphic problems. Stratigraphic cross-sections (Figs. 1, 2) clearly illustrate several salient points. First, the top of the Hopkinton Dolomite can be consistently drawn at the top of Hopkinton C (= *Favosites* Beds of Johnson, 1975), the position at which Calvin originally defined it. Second, the top of the Hopkinton cannot be consistently drawn at the top of the *Pentameroides*-bearing beds. The cross-sections illustrate the fact that the top of the *Pentameroides*-bearing beds does not form a stratigraphic datum, and, additionally, the *Pentameroides*-bearing beds are locally absent. These facts point out the unsuitability of defining a formational boundary at the top of the *Pentameroides*-bearing beds. Third, porous crinoidal facies ("crinoidal bank facies" on cross-sections), included in the Gower Formation by most previous workers, are nowhere laterally equivalent to laminated dolomites. These porous, crinoidal beds should not be included within the Gower Formation since Norton's original definition requires lateral equivalency with laminated dolomites, a definition I prefer to maintain. Therefore, a thick interval of Silurian rocks above the top of the Hopkinton (i.e., *Favosites* Beds) and below the base of the laminated Gower rocks (or their equivalents) cannot, at present, be assigned to a formation if the original formational definitions are utilized. Two options are available to resolve the dilemma: 1) expand the definitions of Gower and/or Hopkinton Formations to include this interval, or 2) erect a new formation to include this interval. I believe the latter choice is preferable, especially since no stratigraphic datum exists with-

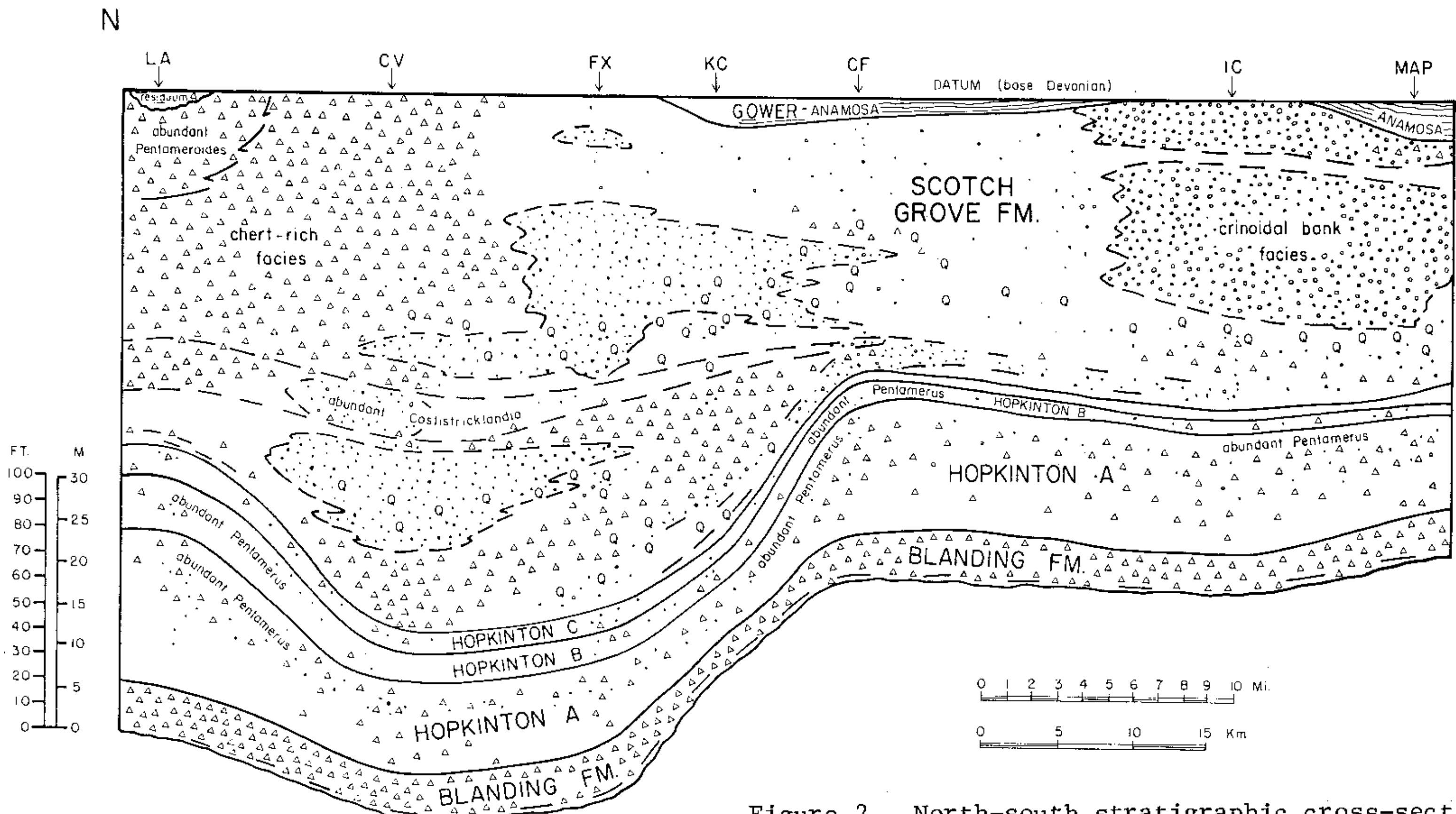

Figure 2. North-south stratigraphic cross-section of the Silurian sequence in Linn and Johnson Counties, Iowa. See Figure 1 for base map. Symbols as in Figure 1. The western extension of the Plum River Fault Zone crosses between localities KC and CF.

in this interval that could be utilized to draw the top of an expanded "Hopkinton" Formation. This unnamed interval is now termed the Scotch Grove Formation (see later discussion).

EAST-CENTRAL IOWA BASIN

The Silurian isopach map (Fig. 3) clearly delineates an eastward-trending basin in east-central Iowa, and the thickest Silurian intervals in this basin presently occur within the Silurian outcrop belt. The maximum known thickness of Silurian rocks in the state, 480 ft (146 m), occurs adjacent to the Plum River Fault Zone in the Silurian outcrop belt of Jones County (Ludvigson and Bunker, 1978). This pre-Middle Devonian basin was first recognized by Lee et al. (1946), who noted "an eastward-trending basin in east-central Iowa." This Silurian basin in eastern Iowa is termed the East-Central Iowa Basin (Bunker, 1981, p. 6). An extensive period of erosion following Silurian deposition removed Silurian carbonate rocks from much of the North American Midcontinent prior to the deposition of Middle Devonian carbonates, and the most complete sequences of Silurian rocks are found only in areas where they were structurally preserved (e.g., East-Central Iowa Basin). The preserved Silurian rocks were then covered and overlapped by Middle Devonian carbonates.

The East-Central Iowa Basin can also be considered a Silurian depositional basin. Stratigraphic cross-sections (Fig. 1) demonstrate a basinward thickening of individual Silurian stratigraphic units, most clearly demonstrated by an eastward doubling in thickness of the Hopkinton Formation. The Silurian development of the East-Central Iowa Basin is characterized by maximum subsidence parallel to the general trend of the present-day Plum River Fault Zone. North-south stratigraphic cross-sections cutting perpendicular to the axis of the western portion of the basin (Fig. 2) illustrate a pronounced thickening of the Silurian interval on the north edge of the Plum River Fault Zone (western limit of fault near Locality KC on Fig. 2). Of special note is the relative uniformity of thickness of the Blanding-Hopkinton interval along the cross-section line, and the Silurian thickening is primarily a function of thickening of the Scotch Grove Formation. In fact, the Scotch Grove interval doubles in thickness over a horizontal distance of only 10 miles (16 km) as one moves from northwestern Johnson into southwestern Linn County. These observations suggest that maximum subsidence in the western portion of the East-Central Iowa Basin occurred during Scotch Grove deposition.

Although there is no evidence of actual faulting along the Plum River Fault Zone during the deposition of the Silurian carbonates, there is close correlation between trends of basinal subsidence in the Silurian and later development of the Plum River Fault Zone. This suggests that deep-seated crustal features have controlled recurrent structural movements along the trend of the Plum River Fault Zone, and these movements have been variably expressed as epeirogenic downwarping (basinal subsidence) and faulting. The distribution of the Bertram and Otis-Coggan Members of the Wapsipinicon Formation with respect to the Plum River Fault Zone "strongly suggests that the fault was active before or during the onset of Middle Devonian deposition in the area" (Ludvigson and Bunker, 1978, p. 24). In conclusion, episodic subsidence of the East-Central Iowa Basin occurred during

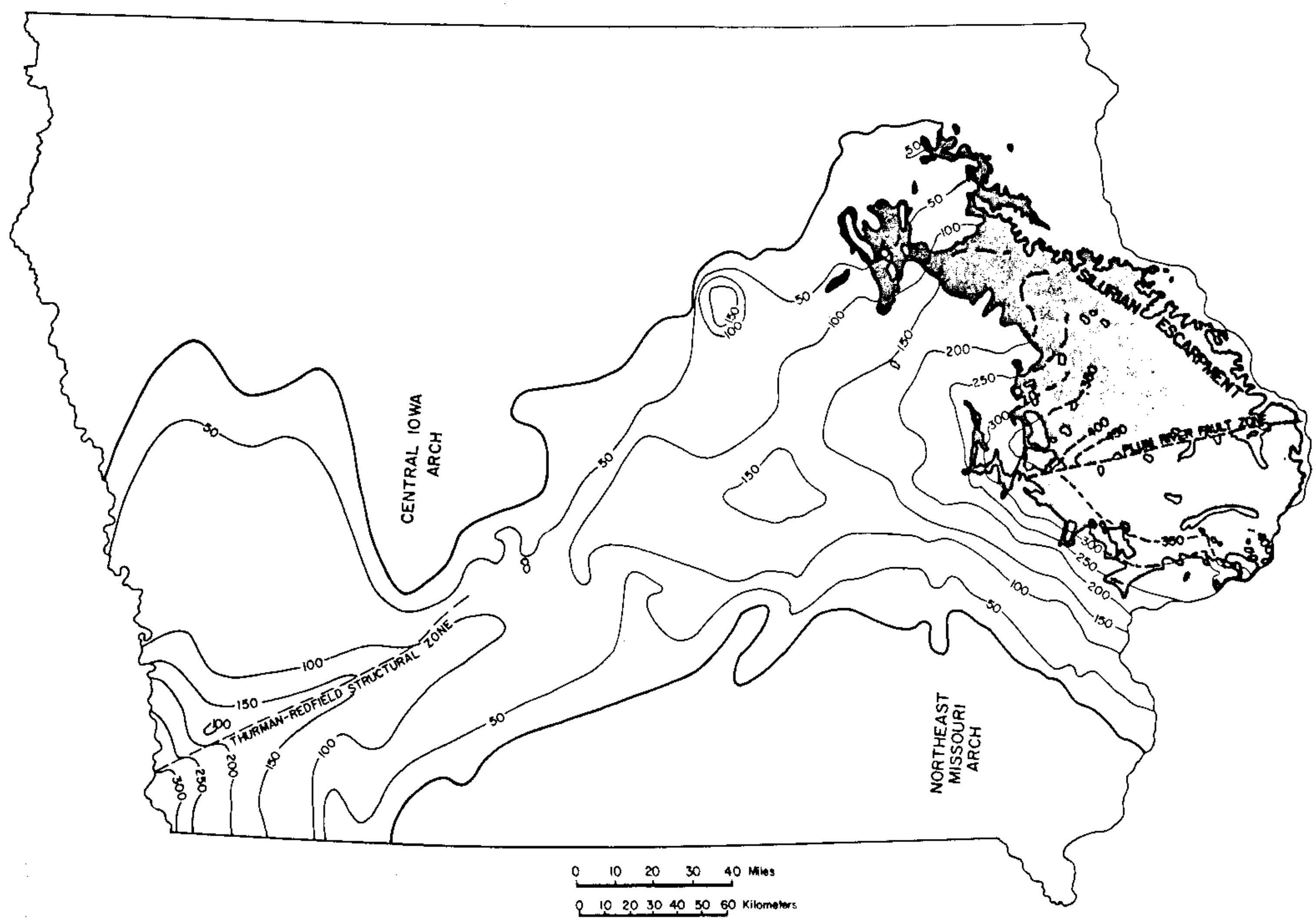

Figure 3. Silurian isopach map (in feet), Iowa. Shaded areas correspond to outcrop belt; elsewhere, Silurian covered by Middle Devonian strata. Dashed lines represent maximum Silurian thicknesses in outcrop belt. Isopachs delineate general area of East-Central Iowa Basin.

Silurian deposition, and prior to the Middle Devonian marine transgression, but probably after Gower deposition, faulting along the Plum River Fault Zone was initiated.

SCOTCH GROVE FORMATION

The Scotch Grove Formation is erected to include the interval above the top of the Hopkinton Formation (top of Favosites Beds) and below the base of the first laminated Gower dolomites. The naming in this field guide of a new formation is not considered an acceptable publication outlet (Stratigraphic Code), and, therefore, the Scotch Grove Formation is used, at present, only as an informal rock unit. Formal publication is forthcoming. No single locality exposes the entire Scotch Grove Formation, and the type locality exposes only the lower portion of the formation in contact with the underlying Hopkinton. Two adjacent abandoned quarries (NW SE SE and SE NW SE sec. 7, T 85, R 2W) north of the town of Scotch Grove, Jones County, are designated the type locality. The upper portion of the Scotch Grove Formation in contact with the overlying Gower Formation will be examined during the course of this field tirp. The Scotch Grove Formation is thickest in the central portion of the East-Central Iowa Basin (about 150-300 feet; 45-90 m), and it thins marginally around the edges of the basin (about 100-170 feet; 30-50 m).

A great diversity of carbonate facies are present within the Scotch Grove Formation including 1) flat-lying, dense, cherty, sparsely fossiliferous dolomites, 2) flat-lying, dense, sparsely fossiliferous dolomites, 3) flat-lying, porous, skeletal-moldic (especially crinoid-moldic) dolomites, 4) mounded (reefal), crinoid-moldic and crinoid-replaced dolomites (wackestone to packstone fabrics), and 5) mounded, dense, sparsely fossiliferous dolomites. This field trip will only focus on the carbonate facies in the upper half of the formation, and lower Scotch Grove facies will be discussed in later publications. Suffice it to say that the lower Scotch Grove Formation is, in many areas, extremely fossiliferous, and these fossils are used to date this part of the formation as latest Llandoverian (C_5,C_6) in age. The upper part of the formation includes fossils of early and middle Wenlockian age, although the age of the upper boundary is not yet completely clarified (probably late Wenlockian). The upper Scotch Grove Formation is divisible into four general lithofacies in the field trip area, and these facies are given geographic names to facilitate later discussion. At the start, it should be stressed that subdividing the Scotch Grove Formation into distinct lithofacies is partly a subjective pigeon-holing attempt, and there is a broad range of overlap and intergradation between some of the described lithofacies. The named lithofacies are intended to be informal stratigraphic units.

Buck Creek Quarry Facies

The most prominent facies in the Scotch Grove Formation is termed the Buck Creek Quarry Facies (after the quarry in NE NW sec. 20, T 87, R 4W, Delaware Co.), and it is predominantly a dense, sparsely fossil-moldic, very cherty dolomite facies. The Buck Creek Quarry Facies includes beds that Johnson (1975) termed the "Pentameroides Beds", but specimens of Pentameroides are only locally present within this facies in the middle portion of the formation. The Buck Creek Quarry Facies is noted in the lower, middle, and upper portions of the Scotch Grove Formation. Nodular to bedded cherts readily serve to distinguish the Buck Creek Quarry Facies from all other upper Scotch Grove facies and all facies in the Gower Formation. The fossil faunas of the Buck Creek Quarry Facies change in character from the lower portions of the Scotch Grove Formation into the upper portions. This trip will visit exposures of the Buck Creek Quarry Facies in the upper portion of the formation where fossils are relatively scarce; molds of small echinoderm debris, corals (Porpites, cup corals, small tabulate coral colonies), brachiopods (Atrypa, Protomegastrophia, gypidulinids, ?Meristina, indet. rhynchonellid, orthids), gastropods, trilobites (Encrinurus), and sponge spicules are noted. Porpites, the "button coral", is especially prominent, and the fossil assemblage is termed the Porpites Association.

Waubeek Facies

The Waubeek Facies, named after exposures near Waubeek, Linn County (NE sec. 17, T 85, R 5W), is characterized by dense to vuggy, sparsely fossil-moldic dolomites. Vugs are locally lined with quartz crystals. It resembles the Buck Creek Quarry Facies in many respects but lacks chert. The Waubeek Facies occurs only in the upper portion of the Scotch Grove Formation, and, as will be seen during the trip, is characteristically sharply overlain by laminated dolomites of the Gower Formation. The Waubeek Facies faunally resembles the upper portion of the Buck Creek Quarry Facies in some respects, although Porpites is conspicuously absent. The Waubeek Facies fauna in the field trip area is characterized by molds of small echinoderm debris, corals (cup corals, small tabulate coral colonies, Heliolites), small bryozoans, brachiopods (Atrypa, Protomegastrophia, gypidulinids, ?Meristina, camerellids, eospiriferids, Hedeina, Resserella, Dalejina), gastropods, trilobites (Encrinurus, Calymene, Bumastus, proetids), and sponge spicules. In areas east of the field trip area, the Waubeek Facies includes beds where the fauna is dominated almost exclusively by small echinoderm debris, and at one locality in Jackson County the Waubeek Facies contains a zone of abundant Rhipidium (a large pentamerid brachiopod). Brachiopod and conodont faunas suggest a mid Wenlockian age for part of the Waubeek Facies. A distinctive and often abundant brachiopod fauna occurs at the very top of the Waubeek Facies beneath the basal laminated dolomites of the Gower Formation at several localities in Jones and Linn Counties. This uppermost Waubeek fauna is termed the Stegerhynchus Association and is characterized by horn corals and brachiopods (Stegerhynchus, Meristina, protathyrids, Spirinella, Coolinia, Resserella, etc.).

Palisades-Kepler Mound Facies

The most complex, and in my opinion the most interesting, facies in the upper Scotch Grove Formation is termed the Palisades-Kepler Mound Facies after the Iowa state park by the same name (Stop 1). This facies is characterized by mounded carbonate buildups ("reefs"), and isolated single mounds and coalesced complexes of mounds are noted. The mounds are characteristically composed of dolomitized skeletal wackestones, packstones, and grainstones. The most abundant skeletal grains (preserved either as molds or as replaced grains) are debris from pelmatozoan echinoderms, and 90 to 100% of the skeletal grains are echinodermal in many mounds of the Palisades-Kepler Mound Facies. Tabulate corals and stromatoporoids are prominent components in portions of the mounds, but the mounds do not have a rigid skeletal framework. Additional skeletal elements are locally prominent. Although skeletal debris is an important constituent of the Palisades-Kepler Mound Facies, the bulk of the mounds is composed of extremely-fine to coarse crystalline dolomite that forms the matrix of the crinoidal wackestones and packstones. Presumably this matrix was originally carbonate mud, and when the mounds were being deposited they were probably composed primarily of carbonate mud. Beds within the carbonate mounds of the Palisades-Kepler Mound Facies dip at angles ranging from 0 to 50°. Beds dip radially away from the mound centers, although within mounded complexes (e.g., Palisades-Kepler State Park) the configuration of dipping beds is very complicated. Within the Palisades-Kepler Mound Facies at some localities, "pockets" up to a few meters across, containing abundant specimens of nautiloids or disarticulated trilobite remains (especially Bumastus), are noted. These "pockets" are characteristically surrounded by typical dolomitized crinoidal wackestone and packstone lithologies. Philcox (1970, p. 178,179) interpreted these nautiloid and trilobite "pockets" to be pene-contemporaneous cave and fissure fills within the mounded rocks.

All previous workers have included the beds here termed the Palisades-Kepler Mound Facies within the "LeClaire Facies" of the Gower Formation. In this study, the LeClaire Facies is still considered a valid term, but only for Gower deposits in the type area of Scott County. With the exception of Philcox (1970, 1972) and Henry (1972), all previous workers have assumed that rocks now included in the Palisades-Kepler Mound Facies (i.e., "LeClaire") are laterally equivalent to laminated dolomites of the Anamosa Facies. Although in the type area the LeClaire Facies is demonstrably laterally equivalent to laminated dolomites, many mounded sequences elsewhere in Iowa have been mistakenly correlated with the LeClaire Facies. The Palisades-Kepler Mound Facies is nowhere laterally equivalent to laminated Anamosa beds, and, in fact, the Palisades-Kepler Mound Facies is overlain by laminated Anamosa beds or their equivalents (Brady Facies). Instead, the Palisades-Kepler Mound Facies can be shown to be laterally equivalent to a variety of facies in the upper Scotch Grove Formation. We will examine some of the lateral relations of the Palisades-Kepler Mound Facies during the course of this field trip. Although all supporting field and subsurface evidence cannot be detailed in this guidebook, suffice it to say that the crinoid-rich Palisades-Kepler mounds are laterally equivalent to the Waubeek, Buck Creek Quarry, and Fawn Creek Facies (introduced in following section).

During deposition, the carbonate buildups of the Palisades-Kepler Mound Facies were expressed as topographic highs on the sea floor. The topographic relief on the upper surface of the Scotch Grove Formation varies locally from a few feet up to 125 feet (38 m), and, therefore, laminated Gower dolomites are locally noted at the same elevation as nearby buildups of the Palisades-Kepler Mound Facies. This fact has undoubtedly influenced previous workers to conclude that the crinoidal buildups and their inter-mound equivalents in the upper Scotch Grove Formation are buried and draped by laminated dolomites and younger buildups of the Gower Formation. The Palisades-Kepler Mound Facies was deposited as local mounded buildups of skeletal debris and carbonate mud, and these buildups were surrounded by flat-lying inter-mound carbonate muds (with sparse to abundant skeletal debris) deposited in slightly deeper water. The presence of fracturing and solutional openings in the mounds pene-contemporaneous with deposition suggests that the mounds were rigid features. The absence of a solid skeletal framework in the mounds, however, suggests that the rigid character of the mounds was the result of submarine cementation processes or unknown organic processes.

The paleontology of the Palisades-Kepler Mound Facies has not been extensively studied, although preliminary work indicates that a diverse assemblage of marine organisms inhabited the mounds. Most prominent of the benthic groups is the pelmatozoan echinoderms. Unidentifiable crinoid debris is usually extremely abundant, and large stem peices up to 1 inch (2.5 cm) in diameter and 6 inches (15 cm) long are noted. Articulated crinoid cups are sometimes preserved, characteristically forms with rigid box-like dorsal cups. Camerate crinoids predominate (Eucalyptocrinites, Calliocrinus, Macrostylocrinus, Dimerocrinites, Siphonocrinus, Marsupiocrinus, Periechocrinus), and inadunate crinoids (Crotalocrinites) and and rhombiferan crystoids (Caryocrinites) are also noted. Tabulate coral colonies are locally prominent (Favosites, Halysites, Syringopora), and and colonial rugose (Arachnophyllum) and solitary rugose (Neozaphrentis, "Cyathophyllum", Ptychophyllum, etc.) corals are also present. Stomatoporoids are locally significant. Brachiopods are abundant in places (Atrypa, Protomegastrophia, Resserella, Rhynchotreta, Ferganella, Eospirifer, Hedeina, Trimerella, etc.), and large pentamerid brachiopods are also noted (Conchidium, ?Lissocoelina). Branching (Rhinidictya) and fenestellid bryozoans are present. Brachiopods, bryozoans, and crinoid debris are sometimes noted in wedge-shaped beds, probably skeletal debris flows. A diversity of nautiloids are present in both the crinoid-rich beds and in "pockets" (Michelinoceras, Dawsonoceras, Kionoceras, Lechritrochoceras, Elrodoceras, Amphicyrtoceras, Phragmoceras, etc.). Gastropods, bivalves, sponge spicules, and green algae (Ischadites) are also noted. Lastly, trilobites (Encrinurus, Calymene, etc.) are encountered in the mounded complexes, especially in Bumastus-rich "pockets".

Fawn Creek Facies

The Fawn Creek Facies is a porous, partly vuggy, skeletal-moldic dolomite facies occurring in essentially flat-lying beds. It is named after exposures in Wapsipinicon State Park (near Anamosa, Jones Co.) along the Wapsipinicon River upstream from the mouth of Fawn Creek. These exposures are well represented along the river and along Dutch Creek in the state park. Faunally and lithologically the Fawn Creek Facies is closely comparable to the Palisades-Kepler Mound Facies. However, unlike the Palisades-Kepler Mound Facies, the Fawn Creek Facies is not developed into mounds, and dolomitized packstones are less abundant. Echinoderm, tabulate coral, and solitary rugose coral molds are the most prominent skeletal remains. In the vicinity of Anamosa, mounded rocks of the

Palisades-Kepler Mound Facies can be traced directly into flat-lying beds of the Fawn Creek Facies, and the two facies are undoubtedly facies equivalents. The Fawn Creek Facies probably represents a non-mounded carbonate mud/skeletal bank facies closely related to the skeletal-rich Palisades-Kepler mounds.

GOWER FORMATION

The Gower Formation, as originally defined and as utilized in this study, includes laminated dolomites and their lateral facies equivalents (in part mounded). As discussed earlier, not all mounded sequences in the Iowa Silurian are laterally equivalent to laminated Gower dolomites, and, therefore, not all mounded features should be included within the Gower Formation. The Gower Formation has been conventionally divided by previous workers into two facies: a laminated Anamosa Facies and a mounded or "reefal" LeClaire Facies. Most previous workers included the Palisades-Kepler Mound Facies of this study within the "LeClaire Facies" and incorrectly inferred lateral equivalency of these mounds with the laminated Anamosa Facies. This procedure has promulgated serious stratigraphic errors and led to an over-simplification of the complex facies relationships in the Scotch Grove and Gower Formations. In this study the LeClaire Facies is applied to the mounded and flat-lying sequences within the Gower Formation of Scott County, and the definition of this facies is restricted to include only those rocks that are known to be equivalent to laminated Anamosa sequences. Three general carbonate lithofacies are recognized in the Gower Formation and are discussed in subsequent paragraphs: Anamosa, Brady, and LeClaire Facies.

The Gower Formation is erosionally truncated beneath Devonian strata in western Linn County and varies from 0 to about 100 feet (30 m) in thickness in eastern Linn and western Jones Counties. Gower sections of up to 100 to 150 feet (30 to 45 m) thick in Cedar and Scott Counties represent the maximum known thickness of the formation. The thickness of the Gower is complementary with that of the Scotch Grove Formation; where the Scotch Grove is thickest (i.e., where the Palisades-Kepler Mound Facies is present) the Gower is thinnest, and vice versa. Structurally-preserved blocks of Gower Formation rocks are noted along the Plum River Fault Zone in southern Jackson and southern Jones Counties. The exact age of the Gower Formation is not known, although its position above Wenlockian carbonates suggests a Ludlovian age, in part, for the Gower Formation. The Gower brachiopod fauna generally supports such an assignment.

Anamosa Facies

As previously discussed, the Anamosa Facies was named for a sequence of laminated dolomite quarrystone and dense dolomite at Stone City, Jones County. The laminated dolomites of the Anamosa Facies include both wavy- (or crinkly-) laminated and planar-laminated rock types; the laminae range from less than a millimeter to about 1 cm in thickness. The laminae are usually uninterrupted and can sometimes be laterally traced along quarry walls for hundreds of feet. The laminated dolomites are interbedded at some localities with dense, microcrystalline to fine crystalline dolomites (ranging from less than 1 cm to more than 1 m in thickness); these dense dolomite interbeds are termed "flints" by quarrymen. Individual "flint" bands are traceable for distances of up to 2 miles (3.3 km) in the Stone City area (Henry, 1972). Skeletal-moldic and skeletal-replaced dolomites are also present in the Anamosa Facies at different localities to varying degrees. At Stone City the Anamosa Facies is largely unfossiliferous, although a few thin bands of brachiopod-moldic and bivalve/ostracode-bearing rocks are noted. At other localities, such as the type Gower section at Cedar Valley (Cedar County), flat-lying beds of skeletal-rich dolomite (skeletal-moldic and skeletal-replaced wackestones and packstones) in excess of 5 feet (1.5 m) thick are noted in the laminated dolomite sequence; these beds contain abundant brachiopods and small tabulate corals. Skeletal-rich beds are most abundant in the Anamosa Facies only in the proximity of Brady Facies mounds. Additional rock types are also noted in the Anamosa Facies at some localities and include: 1) beds of vuggy, sparsely fossiliferous to fossiliferous dolomite, 2) brecciated and intraclastic laminated dolomite, 3) obscurely laminated dolomite, and 4) evaporite-crystal-moldic dolomite. Smooth chert nodules are noted within the Anamosa Facies at several localities.

Skeletal fossils are absent within the laminated dolomites of the Anamosa Facies at most localities, although "rods" (enigmatic rod-shaped bodies about 1 cm x 2 mm) are locally abundant along bedding surfaces. The "rods" have been variably interpreted as fecal pellets or gelatinous dwelling tubes (Henry, 1972). The preservation of thin continuous laminae in the Anamosa Facies indicates that burrowers were generally absent during deposition of the laminated muds. Non-laminated fossil-bearing rocks within the laminated sequence are most frequently characterized by low-diversity brachiopod-rich faunas (*Protathyris*, atrypaceans, rhynchonellids, *Hyattidina*), although corals (small favositids, small cup corals) are sometimes prominent. In addition, bivalves (*Pterinea*), small gastropods, and ostracodes (*Leperditia*, small indet. forms) are present. Crinoid debris molds are sparsely represented in non-laminated dolomites of the Anamosa Facies at some localities, although the general scarcity or absence of echinoderm debris in the Anamosa Facies contrasts markedly with the general abundance of crinoid molds in the underlying beds of the upper Scotch Grove Formation. Trilobites, stromatoporoids, nautiloids, and bryozoans have not been noted in the Anamosa Facies.

The deposition of the laminated Anamosa beds needs to be considered in light of its relation to 1) the sub-Gower surface, and 2) the contemporary mounded Gower facies (Brady Facies). Both considerations suggest that Anamosa Facies deposition began in water deeper than the contemporary Brady Facies mounds, most commonly in areas down-slope from the pre-existing Palisades-Kepler Mounds. The older Scotch Grove mounds were progressively buried by Gower rocks of the Brady and Anamosa Facies. Additionally, the lateral continuity of individual laminae and "flints", the general absence of mudcracks and enrolled laminae, the scarcity of intraclasts, the absence of scour surfaces and wave-washed sediment, and the relation of the laminated rocks to the Brady Facies collectively indicate a subtidal origin for most of the Anamosa Facies. Although supratidal flats and sabkhas are modern examples of environments where laminated sediments can be deposited, the laminated Anamosa rocks differ significantly from such deposits. The wavy- to crinkly-laminations in the Anamosa Facies have been reasonably interpreted as stromatolitic sheets (Philcox, 1972; Henry, 1972), and much of the Anamosa was probably deposited as "subtidal organic mats" (Henry, 1972, p. 96). Planar-laminations in the Anamosa may have been deposited under different conditions, perhaps as rhythmic alternations during carbonate precipitation. The laminated rocks of the Anamosa Facies are characterized by an absence of burrowers and general scarcity or absence of benthic organisms. These features suggest benthic conditions were hostile to many organisms. Additionally, in the non-laminated beds of the Anamosa Facies, skeletal fossils are commonly absent, and, when present, are characterized by low-diversity communities. The absence or scarcity of several probably stenohaline groups of organisms (trilobites, nautiloids, stromatoporoids, echinoderms) further suggests that benthic conditions were unsuitable for many common marine organisms. Philcox (1972, p. 701) interpreted the depositional environment of the Anamosa Facies as one of "low energy", "hostile to most organisms", perhaps in a situation of "restricted circulation" that "led to high salinities." Henry (1972, p. 78) also suggested that the Anamosa Facies "was deposited under unusual, possibly highly saline, conditions in which a normal marine fauna could not develop." The presence of hypersaline waters during Anamosa deposition is further suggested by the presence of evaporite crystal molds (probably gypsum) in the Anamosa at Stone City (Henry, 1972). The Anamosa Facies shares a number of similarities with carbonate rocks of the A-1 evaporite cycle in the Silurian of the Michigan Basin, although salinities during deposition of the Anamosa Facies never reached concentrations high enough to begin precipitation of halite. What conditons in eastern Iowa might be responsible for the change from "normal" marine deposition in the upper Scotch Grove Formation to hypersaline deposition in the Anamosa Facies? Clearly, some change in circulation needs to be invoked, and a barrier to open circulation is undoubtedly necessary. I propose that the progressive regression of the seas during the Middle and Late Silurian left central Iowa emergent at the beginning of Gower deposition, and open circulation across the carbonate shelf was thereby cut off. This situation would have left east-central Iowa as a restricted embayment of the Silurian sea. Such an interpretation is further corroborated by the fact that laminated Gower rocks are only noted within the general confines of the East-Central Iowa Basin.

Brady Facies

Philcox (1970) named the Brady Facies after the Brady (McGuire Quarry) in Cedar County (SE sec. 14, T 80, R 3W). The Brady Facies is characterized by mounded sequences of fossil-moldic and fossil-replaced dolomites (wackestone, packstone, and boundstone fabrics) with abundant brachiopods and/or rugose corals (*Fletcheria*). Dense non-laminated to laminated dolomites, in part with prominent domal stromatolites, are interbedded with the fossil-rich beds. General rock types present in the Brady Facies resemble those of the Anamosa Facies, although the Brady Facies is markedly more skeletal-rich. The Brady Facies is laterally equivalent to flat-lying laminated dolomites of the Anamosa Facies and is known to overlie upper Scotch Grove Formation strata of the Waubeek, Buck Creek Quarry, and Palisades-Kepler Mound Facies. Beds generally dip radially outward from the central area of the Brady mounds, although smaller "satellite" mounds locally alter this general picture. Dips average between about 10 and 50°, but S-shaped "slump folds" in the Brady Facies locally achieve dips up to 90° (Hinman, 1963; Smith, 1967; Philcox, 1972).

At Palisades-Kapler State Park the Brady Facies occurs in stratigraphic position above the crinoidal mounds of the Palisades-Kepler Mound Facies, and Philcox defined the base of the Brady Facies at the base of the lowest brachiopod-rich bed (which is laterally equivalent to the basal laminated Anamosa dolomites). "The contact appears to represent a time-surface . . . there is no evidence for interfingering between the Brady and crinoid-coelenterate facies [i.e., Palisades-Kepler Mound Facies] . . . the Brady facies at the Palisades characteristically takes the form of large-scale wedge-beds with dips up to about 45°, which thin and flatten out down dip" (Philcox, 1970, p. 176). These exposures and others in Linn, Cedar, and Jones Counties demonstrate that the mounded Brady Facies is, in part, developed on the tops and flanks of the older crinoid-rich carbonate buildups of the Palisades-Kepler Mound Facies. Additionally, the Brady Facies carbonate mounds probably acted as loci for the distribution of skeletal debris that spread laterally away from the mounded areas and interfingered with the inter-mound laminated carbonates of the Anamosa Facies. The lateral equivalence of the Brady and Anamosa Facies is clearly displayed at several localites in eastern Iowa (e.g., Stop 2), and if individual bedding surfaces are traced along exposures displaying these relations, the Brady Facies is noted to be two to more than five times greater in thickness than the equivalent beds in the Anamosa Facies. This observation suggests that the Brady Facies mounds were developed as topographic highs above the surrounding inter-mound area where laminated carbonate mudstone deposition was taking place, and the tops of the Brady Facies mounds were, therefore, deposited in slightly shallower environments than the equivalent beds in the Anamosa Facies.

The Brady Facies represents a second stage of carbonate mound building above the older buildups of the Palisades-Kepler Mound Facies at several localities, and additional, apparently co-extensive, Brady Facies mound development expanded laterally away from the older Scotch Grove buildups into the area previously occupied by the inter-mound Waubeek or Buck Creek Quarry Facies (as at Stop 2). The Brady Facies is interpreted to both bury and spread laterally away from the older Palisades-Kepler Mound Facies developments. The type area of the Gower Formation near Cedar Valley, Cedar County, will not be visited during this field trip, but the stratigraphic relations there clarify, in part, the position of the Brady Facies (Fig. 4). In the Cedar Valley area the Brady Facies is clearly developed on the flanks (and crest?) of an older crinoid-rich buildup in the Scotch Grove Formation, and wedge-shaped beds of Brady Facies brachiopod-rich rocks interfinger down dip with laminated dolomites. Downstream from the exposures of mounded Brady and Palisades-Kepler Facies (Locality CVR on Fig. 4) the type locality of the Gower Formation exposes a thick sequence of flat-lying laminated Anamosa rocks (Locality CVQ on Fig. 4). The base of the Cedar Valley quarry lies about 130 feet (40 m) lower in elevation than the highest beds of the Palisades-Kepler Mound Facies at locality CVR (Fig. 4). Therefore, the Scotch Grove-Gower contact locally displays at least 130 feet (40 m) of vertical relief. Since the Scotch Grove and Gower Formations do not generally interfinger, the inferred stratigraphic relations shown in Figure 4 suggest that the carbonate buildups of the Palisades-Kepler Mound Facies in this area were pronounced topographic highs at the time Gower deposition began. Brady

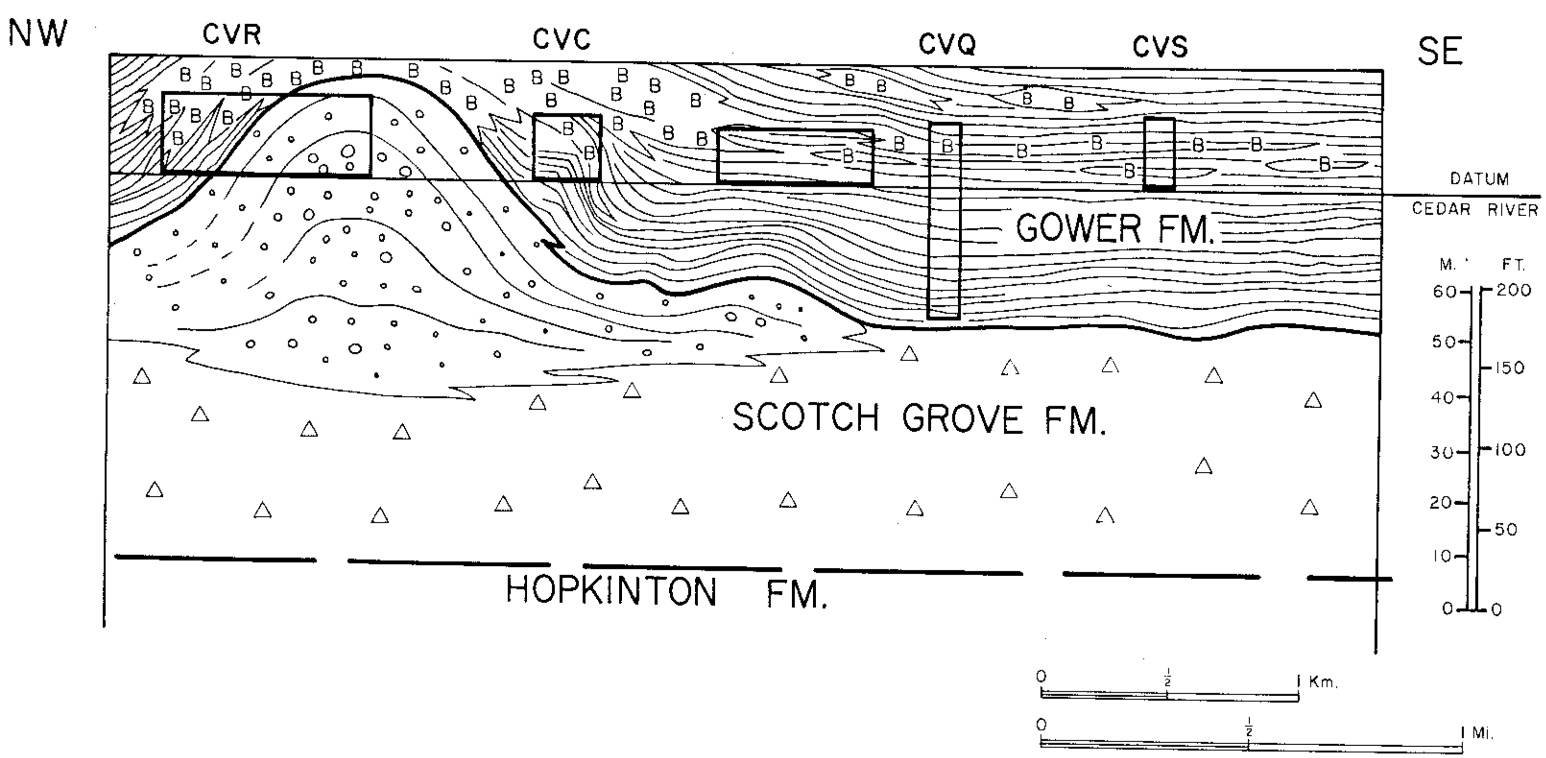

Figure 4. Interpretive stratigraphic cross-section in the type area of the Gower Formation (Cedar Valley, Cedar Co., Iowa). Boxed areas correspond to outcrop control. Small circles--crinoidal Palisades-Kepler Mound Facies, triangles--chert, B--brachiopod-rich rock (Brady Facies), lined area--laminated Anamosa rocks.

Facies deposition was initially restricted to the vicinity of the older Palisades-Kepler mounds while laminated Anamosa carbonates were deposited between the mounds. As Gower deposition proceeded, the Brady Facies and related brachiopod-rich sediments spread laterally away from the old mound centers into former inter-mound regions.

The fossil fauna of the Brady Facies is primarily characterized by an abundance of brachiopods, and literally millions of brachiopods are exposed at some Brady Facies outcrops. Most brachiopods are small (less than 1 cm). Large numbers of a few species characterize most Brady Facies brachiopod faunas (Protathyris, indet. rhynchonellids, Hyattidina, cyrtiids, ?Fardenia). Preservation of delicate brachiopod spiralia and spondylia is noted in some brachiopod-rich beds of the Brady Facies. An additional brachiopod association is noted only in the central portion of Brady Facies mounds and includes Atrypa, Leptaena, ?Sphaerirhynchia, orthids, stropheminids, Trimerella, and ?Capelliniella (a large pentamerid reaching lengths to 10 cm). Clusters of rugose corals (Fletcheria) are prominent in many Brady Facies mounds, and the rugose corals can form boundstones of cemented "reef" rock (remnant fibrous cement fabrics are noted, probably originally submarine aragonite cements). A small favositid tabulate coral is locally prominent in portions of some Brady Facies mounds, and small zaphrentid cup corals, Favosites, and Halysites are also noted. Additionally, ostracodes, small gastropods, bivalves (Pterinea), and rare nautiloids are locally present. Domal stromatolites are developed in the Brady Facies at some localities, and green algae (Ischadites) are also noted. While echinoderm debris has been noted in the Brady Facies at some localities, it is characteristically rare to absent. Trilobites, bryozoans, and stromatoporoids are absent in the Brady Facies mounds. The absence or scarcity in the Brady Facies of many "normal marine" groups commonly represented in the older Palisades-Kepler Mound Facies is noteworthy, and, as with the Anamosa Facies, the physical environment posed stresses that excluded several groups of marine organisms. Elevated salinities are suggested. However, during deposition the physical conditions in the Brady Facies were suitable for the fluorishing of generally low-diversity brachiopod and coral faunas, unlike the extremely hostil envioonments of the laminated Anamosa Facies where most benthic organisms were excluded. The Brady Facies developed in waters that were generally shallower than the inter-mound Anamosa Facies, and near-surface water conditions were apparently more favorable for the fluorishing of benthic organisms than the slightly deep environments where subtidal organic mats and "evaporitic" carbonates were deposited. This observation suggests a vertical stratification of the water column during Gower deposition. The probability of hypersaline conditions during Gower deposition further suggests that a halocline was established in east-central Iowa in which the denser, more saline waters were present beneath an upper surface layer of less saline and better aerated waters. I propose that the Brady Facies mounds developed in the shallower and more hospitable surface waters, whereas deposition of the Anamosa Facies predominated beneath a halocline.

LeClaire Facies

During this field trip we will not examine any exposures of the LeClaire Facies (sensu stricto), and discussion of this facies is therefore minimized in this guidebook. The LeClaire Facies in the type area of eastern Scott County includes both mounded and flat-lying sequences of dense, crystalline dolomite varying from unfossiliferous to very fossiliferous. Like the Brady Facies, small brachiopod and horn coral (Fletcheria) molds are prominent in many exposures of the LeClaire Facies. Additionally, at several Scott County exposures the LeClaire Facies is developed as flat-lying beds, unlike the Brady Facies which is only known to occur as a mounded facies (which interfingers with flat-lying Anamosa beds). The LeClaire Facies is interbedded with laminated Anamosa rocks at several Scott County exposures, and, therefore, the LeClaire Facies can be logically included within the Gower Formation. Although the LeClaire Facies resembles the Brady Facies in several respects, important differences serve to differentiate the two facies. Some features are noted only in the Brady Facies but not in the LeClaire Facies: 1) great profusion of abundant brachiopod-moldic and-replaced wackestones and packstones, 2) large domal stromatolites, and 3) high-angle dips and "slump folds". Features noted only in the LeClaire Facies that are not observed in the typical Brady Facies exposures include: 1) abundant crinoid-moldic wackestones, 2) nautiloid-rich "pockets" and beds, and 3) presence of trilobites. The presence of crinoidal debris in the LeClaire Facies (both mounded and flat-lying sequences) is especially noteworthy, since the Brady Facies is characterized by the absence or scarcity of echinoderm remains. The presence of crinoidal wackestones, tabulate coral-bearing beds, and nautiloid-rich "pockets" in the LeClaire Facies of Scott County is reminiscent of the Palisades-Kepler Mound Facies, and, in this regard, it is understandable how the term "LeClaire" was extended by many previous workers to include strata now assigned to the Palisades-Kepler Mound Facies. The most important stratigraphic distinction between these two facies is the lateral equivalence of the LeClaire Facies and the laminated Anamosa Facies, whereas the Palisades-Kepler Mound Facies is laterally equivalent to non-laminated facies in the upper Scotch Grove Formation.

The LeClaire Facies includes a more diverse assemblage of fossils than the other Gower facies, and the presence, often in abundance, of several "normal marine" groups (crinoids, nautiloids, trilobites) is of considerable significance. The LeClaire Facies probably developed in a situation analogous to the Brady Facies, i.e., as mounded carbonate buildups and banks laterally equivalent to laminated Anamosa beds. A halocline probably extended across eastern Iowa into Scott County, beneath which laminate carbonate deposition predominated. The LeClaire Facies probably was deposited above the halocline. The presence of a more "normal marine" biota in the LeClaire Facies of Scott County, compared to the more "restricted" biota of the Brady Facies, suggests that surface water conditions (i.e., above the halocline) were more favorable for a greater diversity of organisms in Scott County than they were farther west (Jones, Linn, Cedar Counties). This suggests that during Gower deposition surface water salinities increased westward within the East-Central Iowa Basin. A tentative model for Gower deposition is proposed in which a restricted embayment of the Silurian sea in east-central Iowa opened eastward into Illinois where better circulation and more normal marine salinities prevailed. Carbonate buildups and skeletal/mud banks of the LeClaire Facies in the eastern portion of the East-Central Iowa Basin may have served to attenuate open marine circulation between Illinois and eastern Iowa.

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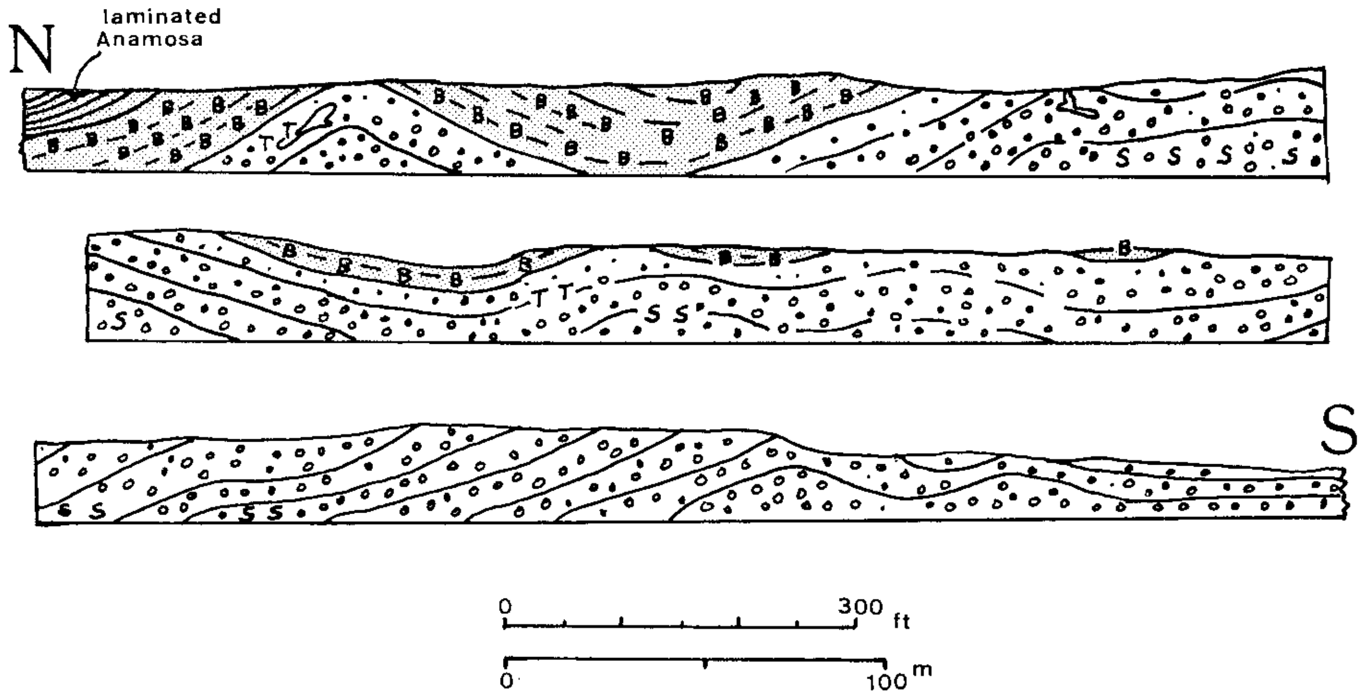

Figure 5. General configuration of Silurian strata in the western portion of Palisades-Kepler State Park (Stop 1), Linn County, Iowa (adapted from Philcox, 1970). Small circles--crinoidal Palisades-Kepler Mound Facies, T--prominent tabulate corals, S--prominent stromatoporoids, shaded area--Gower Fm., B--brachiopod-rich Brady Facies.

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ROAD LOG AND FIELD STOP DESCRIPTIONS

STOP 1. Palisades-Kepler State Park (E½ SW¼ sec. 14, T 82, R 6W, Linn Co.). Type locality of Palisades-Kepler Mound Facies of the Scotch Grove Fm. This is a state park, and rock hammers and sample collecting are not permitted. We will proceed by trail in an upstream direction (north and west). The crinoid-rich rocks of the Palisades-Kepler Mound Facies are well exposed along the trail. Note the directions of dip and general lithologic characteristics of this facies. Crinoid debris molds and dolomitized crinoid stems are the primary skeletal constituent of the Palisades-Kepler Mound Facies in crinoidal wackestone and packstone fabrics. Crinoid cups are visible in some rock faces. Tablate corals (Favosites, Halysites) and stromatoporoids are locally prominent. Additionally, rugose corals, gastropods, nautiloids, trilobites, bryozoans, and brachiopods are present. The general distribution of rock types in the state park is shown on Figure 5, and the Palisades-Kepler Mound Facies is interpreted to be a series of coalesced mounded features termed a mounded complex. We will continue along the trail until we reach exposures of the Brady Facies (Gower Fm.) lying in stratigraphic position above dipping crinoidal beds of the Palisades-Kepler Mound Facies. Note the abundance of brachiopod molds and complete absence of echinoderm debris in the Brady Facies, unlike the underlying strata. The stratigraphic position and lithologic character of the Brady Facies clearly distinguish it from the underlying Palisades-Kepler Mound Facies.

Although we will not be able to visit many of the exposures in the vicinity of the state park, Figure 6 illustrates the lateral relationships of the Palisades-Kepler Mound Facies to adjacent facies. Moving

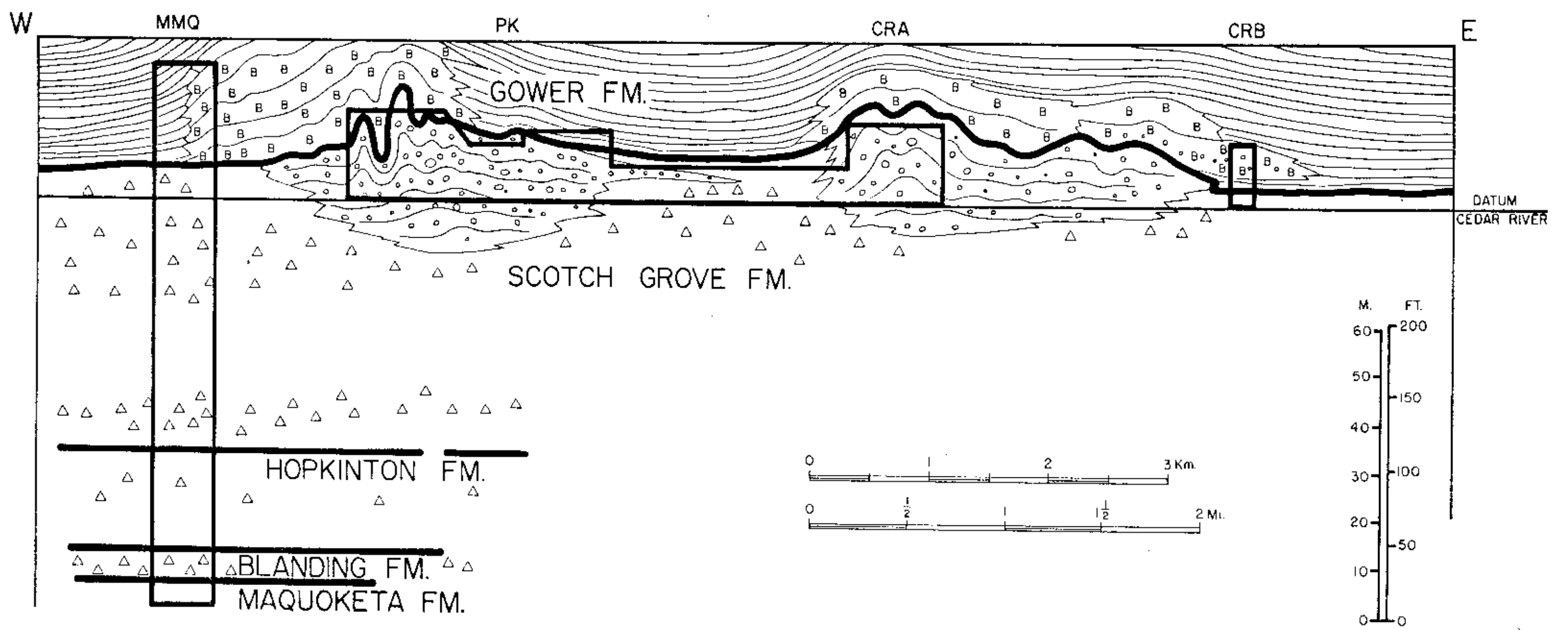

Figure 6. Interpretive stratigraphic cross-section in the vicinity of Palisades-Kepler State Park, Linn County, Iowa. Boxed areas correspond to outcrop or core control. Symbols as in previous figures. Note that the mounds at Palisades-Kepler State Park are laterally equivalent to cherty dolomites of the upper Scotch Grove Formation. (PK--Stop 1, MMQ--Stop 2).

downstream from the state park the mounded complex becomes less skeletal-rich and more flat-bedded and grades into flat-lying, cherty, dense dolomites assigned to the Buck Creek Quarry Facies (Scotch Grove Fm.). This relationship is especially significant stratigraphically since the Palisades-Kepler Mound Facies is not laterally equivalent to laminated Anamosa rocks and, therefore, should not be included within the Gower Formation. West from the state park, the Martin-Marietta Quarry displays laminated and mounded Gower rocks in stratigraphic position above the Buck Creek Quarry Facies of the Scotch Grove Formation. The exposures in the vicinity of Palisades-Kepler State Park are critical to understanding the facies relations within the upper Scotch Grove and Gower Formations: 1) the Palisades-Kepler Mound Facies and Buck Creek Quarry Facies are lateral facies equivalents in the Scotch Grove Formation, 2) the Brady and Anamosa Facies lie stratigraphically above the Scotch Grove Fm., and 3) the Brady and Anamosa Facies are lateral facies equivalents in the Gower Formation.

mileage

0.0 Leave parking area.
0.4 Bear left and return to park entrance.
1.8 Hwy 30, turn left (west).
4.4 Intersection of Hwys 30 and 13. Continue west on Hwy 30.
5.1 Cross Cedar River and turn left; bear left and follow road into Martin-Marietta Quarry. Note bluff and roadside exposures of the Wapsipinicon Formation. This is the Skvor-Hartl structural area where Wapsipinicon rocks are down-dropped and deformed along the western extension of the Plum River Fault Zone (1978 GSI trip and 1978 Tri-State Guidebook).
7.0 Scale house; proceed into quarry.
7.6 Stop at bottom of quarry near south wall and park.

STOP 2. Martin-Marietta Quarry, Cedar Rapids (SW NE sec. 15, T 82, R 6W, Linn Co.). Hard hats are required. Please be cautious along quarry walls. This is one of the largest quarries in the state. We will begin at the bottom of the quarry and proceed up through the stratigraphic sequence. The upper portion of the Scotch Grove Formation is well exposed in the bottom portion of the quarry (about 40 ft; 12 m thick). The upper Scotch Grove sequence is characterized by dense to vuggy, bedded, partly cherty dolomites. The presence of chert allows assignment of this sequence to the Buck Creek Quarry Facies, although the beds at this locality are significantly less cherty than most exposures of the Buck Creek Quarry Facies. The dolomites include scattered molds of small echinoderm debris, cup corals, brachiopods (*Atrypa*, *Dalejina*), and bryozoans (*Rhinidictya*). Compared to the equivalent and highly fossiliferous Palisades-Kepler Mound Facies, the Buck Creek Quarry Facies is only sparsely fossiliferous. Proceed from the lower quarry level upsection along the ramped roadways. We will stop at the Scotch Grove-Gower contact. The contact is sharp and is drawn at the base of the first laminated dolomites of the Anamosa Facies. The laminated dolomites are planar to crinkly laminated, and, in places, the beds are clearly stromatolitic. "Rods" are prominent along some bedding planes. From our vantage point along

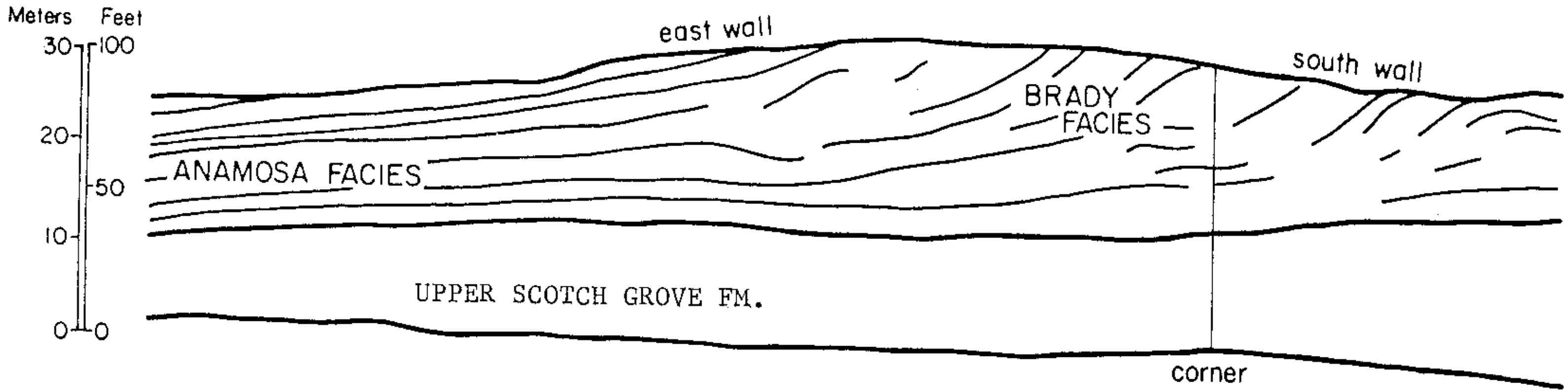

Figure 7. Southeast corner of Martin-Marietta Quarry, Cedar Rapids (Stop 2). Diagram traced from photo-mosaic. Note the lateral equivalence of the mounded Brady Facies and flat-lying Anamosa Facies in the Gower Formation.

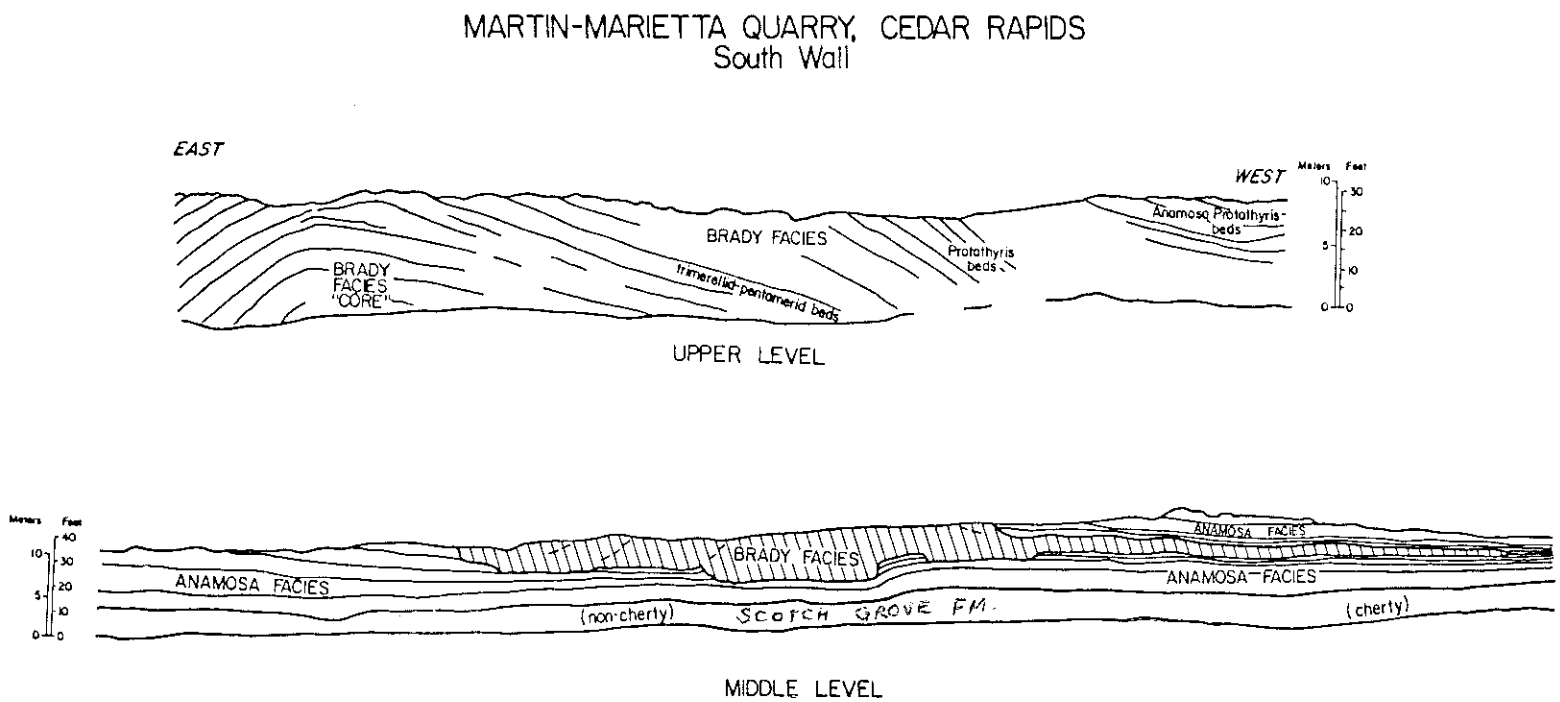

Figure 8. Quarry exposures along the south wall, Martin-Marietta Quarry, Cedar Rapids (Stop 2). Beds traced from photo-mosaic. Note equivalence of Brady and Anamosa Facies.

the west wall, observe the beds near the southeast corner of the quarry (Fig. 7). The flat-lying Anamosa beds merge into dipping beds of a large Brady Facies carbonate buildup. Proceed along the middle level of the south wall. Note the interfingering and lateral equivalence of the flat-lying laminated rocks of the Anamosa Facies and the mounded, non-laminated Brady Facies rocks (Fig. 8). Proceed to the upper level along the south and east walls. The flat-lying Anamosa beds grade south into the Brady Facies and become progressively interbedded with skeletal-rich Brady Facies rocks. Brachiopod-rich dolomites (rhynchonellids, Protathyris) are especially prominent, and literally millions of brachiopods are exposed along portions of the quarry wall. Proceed to the central portion of the Brady Facies mound where the beds dip radially away from the "core" area (Fig. 8). Note that the rocks remain well bedded, and no structureless "core" is present. The central area of the mound is characterized by a greater diversity of fossils among which tabulate corals and brachiopods (Atrypa, Trimerella, ?Capelliniella, etc.) are prominent. Horn corals, gastropods, nautiloids, and sparse echinoderm debris are also noted. Additionally, note the botryoidal cement coatings on some of the skeletal grains. Participants will have to collect fossil and rock specimens. Return to cars.

7.6 Leave quarry and return to Hwy 30.
9.8 Turn east (right) on Hwy 30.
10.5 Turn north on Hwy 13.
11.1 Note roadcuts in Otis Mbr., Wapsipinicon Fm. Do not stop (Emmanuella brachiopods can be collected here).
22.9 Turn east (right) to Whittier on Linn Co. Hwy E34.
27.4 Whittier; turn north on Linn Co. Hwy X20.
32.4 Enter Waubeek. F.B. & Co. bar by the Wapsipinicon River bridge is open at 12 noon Sunday (food and restrooms available). Potential lunch stop here or at Sigmund Memorial Site on opposite bank of river. Quarry in Anamosa Facies adjacent to bar.
32.9 Turn east (right) on Linn Co. Hwy E28 (gravel road).
33.1 Dolomite outcrops, Waubeek Facies.
33.5 Roadcuts along Wapsipinicon River. Type locality of Waubeek Facies. Park cars along right edge of road. Please be cautious on roadway.

STOP 3. Exposures of Waubeek Facies (NE sec. 17, T 85, R 5W, Linn Co.). a 42-foot (12.9 m) thick sequence of the Waubeek Facies, upper Scotch Grove Formation is accessible here. The Waubeek Facies occupies the same stratigraphic position as the Buck Creek Quarry Facies at Stop 2 but is distinguished by the absence of chert. Note the close similarities of the dolomites at Stop 3 to those in the upper Scotch Grove at Stop 2. The Waubeek Facies consists of thin to thick bedded, sparse-fossil-moldic, vuggy dolomite. The vugs in the lower 11 feet (3.4 m) of the sequence are, in part, line with small quartz crystals. A variety of fossils have been collected at this locality (Fig. 9), although they are generally rare and large volumes of rock need to be mechanically broken in order to collect them. Small molds of crinoid debris are noted throughout the sequence and are more prominent in the upper 8 feet (2.5 m). Additionally, brachiopods, bryozoans, corals, sponge spicules, and trilobites are noted in some beds.

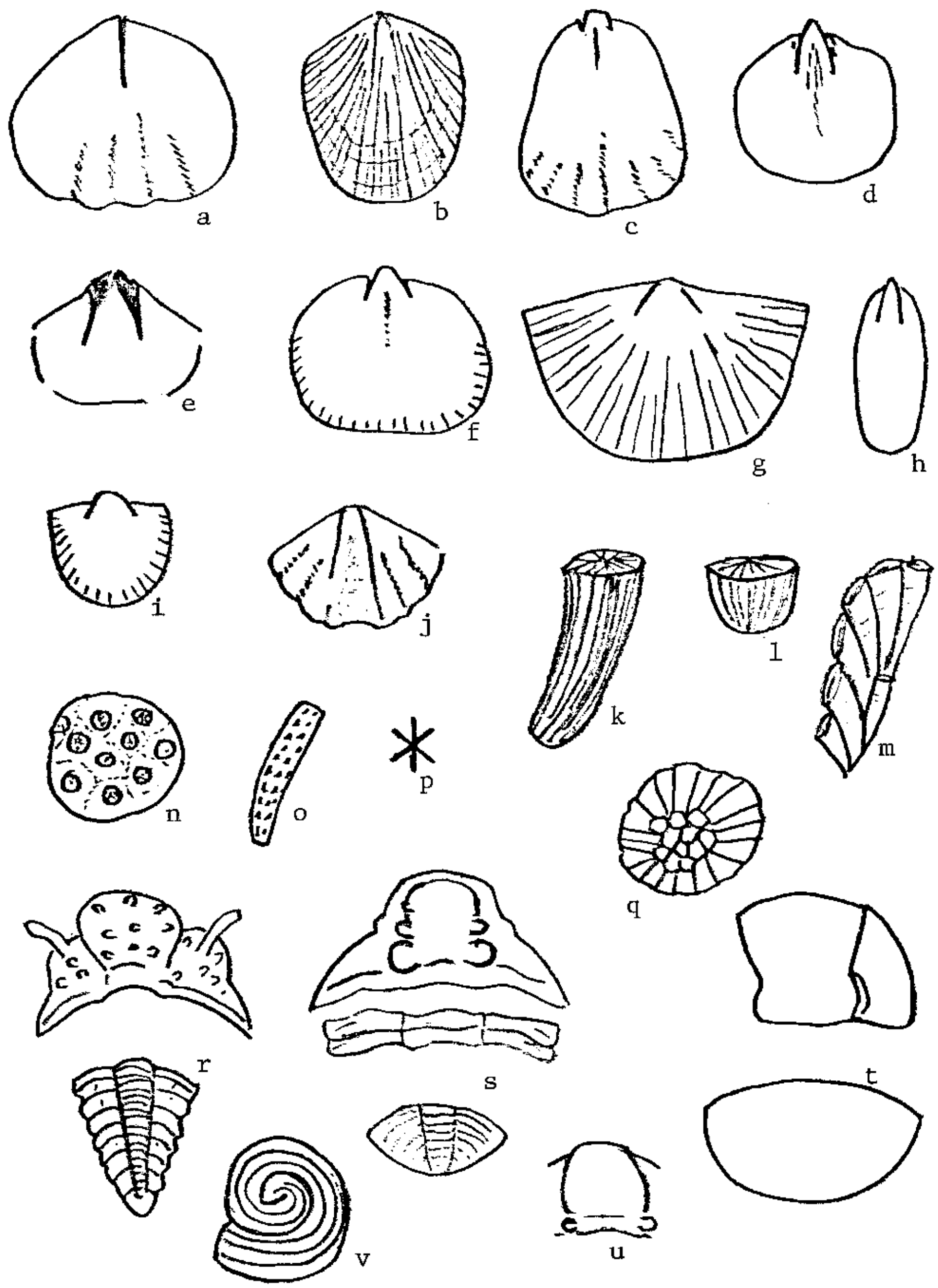

Figure 9. Fossils noted at the type locality of the Waubeek Facies, Scotch Grove Fm., Stop 3. a. gypidulinid, b. *Atrypa* sp., c. camerellid, d. ?*Meristina*, e. cyrtiid (partial specimen), f. *Dalejina* sp., g. *Protomegastrophia* sp., h. indet. brachiopod, i. *Resserella* sp., j. *Hedeina* sp., k. horn coral, l. cup coral, m. *Halysites* sp., n. *Heliolites* sp., o. bryozoan, p. sponge spicule, q. indet. small tabulate coral, r. *Encrinurus* sp. (cephalon, pygidium), s. *Calymene* sp. (ceph., thoracic segments, pyg.), t. *Bumastus* sp. (ceph., pyg.), u. proetid sp. (cranidia), v. gastropod. All approx. 2x to 3x.

33.5 Proceed east.
33.9 Quarry in Waubeek Facies.
34.1 Last outcrop of Waubeek Facies along road.
35.8 Stop sign; turn right on paved road and proceed 0.4 mi.
36.2 Turn right onto gravel road.
38.0 Turn right.
39.4 Matsall Bridge Quarry on east side of road. Park along right edge of roadway. Please be cautious on roadway.

STOP 4. Matsall Bridge Quarry (NW NW sec. 36, T 85, R 5W, Linn Co.). Please be cautious along quarry walls (loose rock). Hard hats are required. A 50-foot (15 m) thick sequence of the Buck Creek Quarry Facies (upper Scotch Grove Fm.) is accessible on and above the quarry walls. The dolomites exposed here are sparsely skeletal moldic, thin to thick bedded, and vuggy (part calcite filled). The sequence is very cherty, and chert nodules are scattered in bands every 20 to 100 cm. Notice the large lens-shaped body in the middle portion of the east wall. What might this feature be? Fossils are scattered

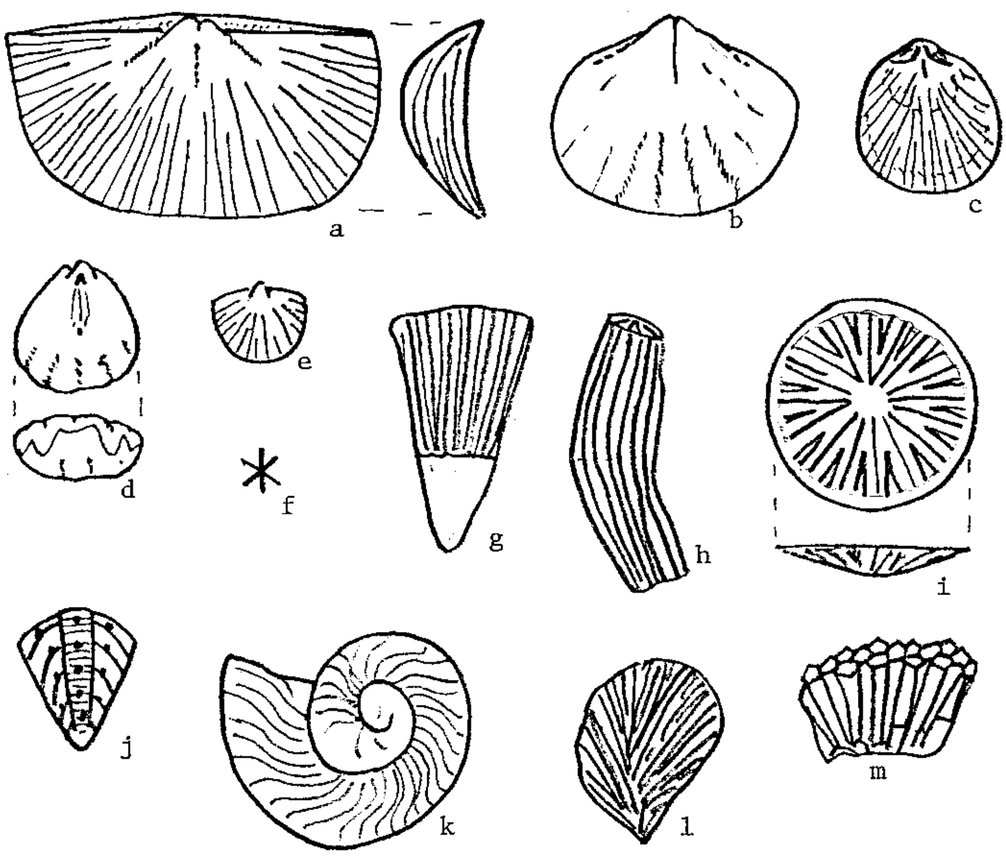

Figure 10. Fossils from the Buck Creek Quarry Facies, upper Scotch Grove Formation, Stop 4, middle portion of north wall. a. *Protomegastrophia* sp., b. gypidulinid, c. *Atrypa* sp., d. indeterminate rhynchonellid, e. orthid, f. sponge spicule, g. cup coral, h. horn coral, i. *Porpites* sp. ("button coral"), j. *Encrinurus* sp. (trilobite pygidium), k. gastropod, l. small tabulate coral, m. favositid tabulate coral. All approx. 2x to 3x.

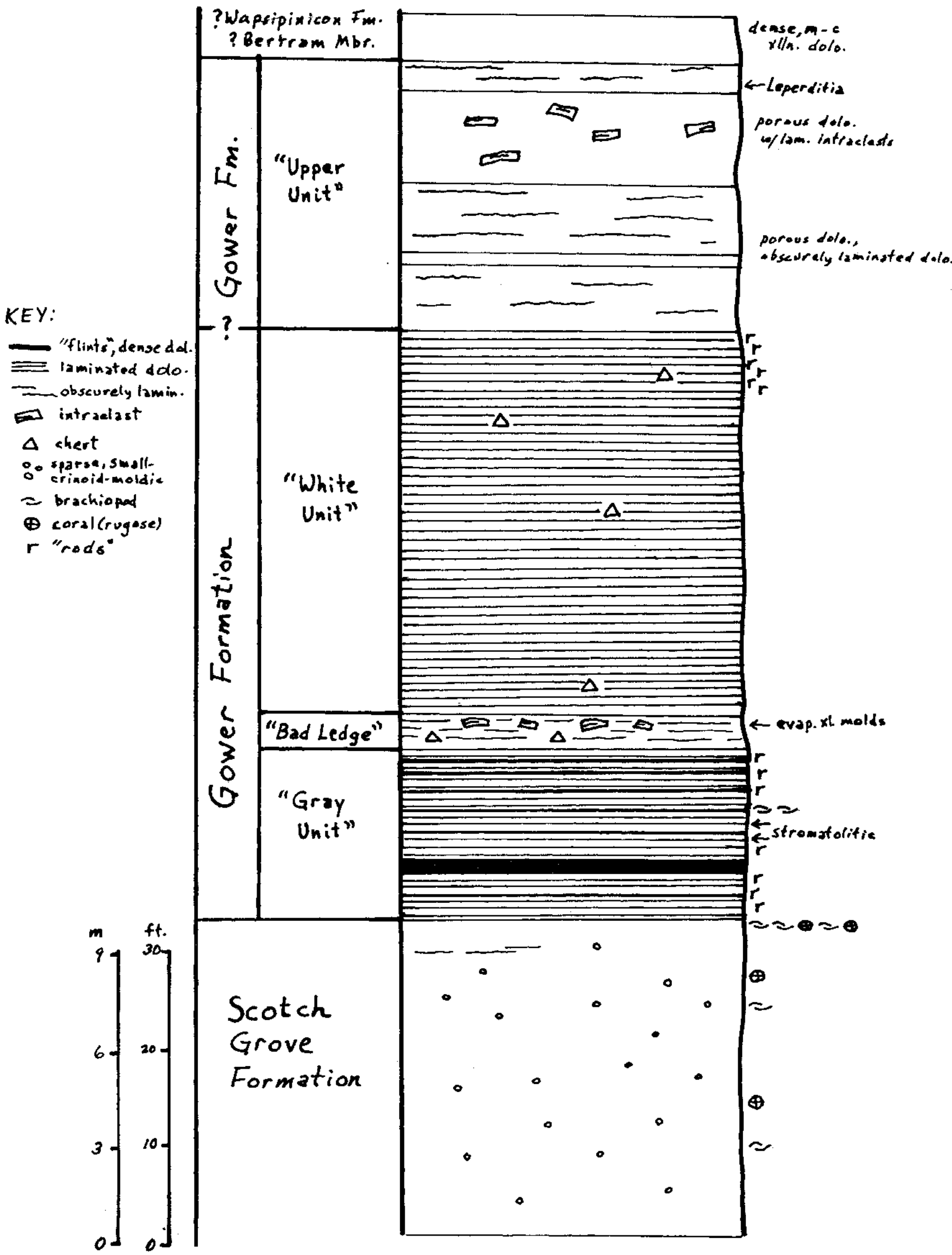

Figure 11. Composite stratigraphic sequence, Stone City, Jones Co., Iowa. Adapted largely from Henry (1972).

throughout the sequence, and small echinoderm debris and cup coral molds are commonly noted. Fossil collecting is best in the talus along the north wall, and fossils are most easily found by mechanically breaking the rock apart. The "button coral" Porpites is especially prominent, although other fossils can also be found (Fig. 10). The upper Scotch Grove dolomite sequences that we've examined at Stops 2, 3, and 4 are very similar. However, Stop 3 is chert-free, Stop 2 is sparsely cherty, and Stop 4 is very cherty. What diagenetic controls might influence the distribution of chert in the inter-mound Waubeek and Buck Creek Quarry Facies in the upper Scotch Grove Formation.

39.4 Proceed south.
39.8 Cross Wapsipinicon River (Matsall Bridge Public Access).
41.3 Stop sign. Turn left.
42.0 Mt. Hope Public Access area on left (large quarry developed in laminated Anamosa Facies, Gower Fm.).
42.3 Old Champion Quarry (Anamosa Facies) on right. Site of Grant Wood art colony. Note abandoned quarry buildings, large stone horse barn, and the "Green Mansion" near the hilltop.
42.5 Stop sign. Stone City.
42.8 Weber Stone Co. entrance by Wapsipinicon River bridge. Parking may be a major problem here if the quarry gate is not open. If gate is open, drive vehicles into quarry. If not, try to find a safe parking place along roadway and walk into quarry.

STOP 5. Weber Stone Co. (NE sec. 6, T 84, R 4W, Jones Co.). Please wear hard hats and be cautious along quarry walls. A thick sequence of upper Scotch Grove-Gower rocks is available for study in the Stone City area (see Fig. 11). This is the type locality for the Anamosa Facies. The field trip participants are encouraged to read Dorheim and Anderson (1978, 42nd Tri-State Geol. Conf.,Iowa Geol. Survey, p. 5-1 - 5-10) for a more complete picture of Stone City history and quarry operations. We will begin in the lowest level of the quarry

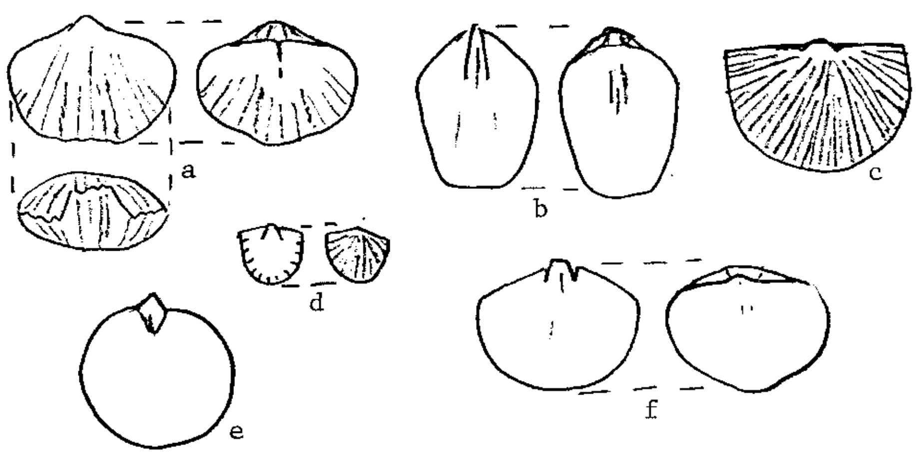

Figure 12. Brachiopods from the uppermost bed of the Scotch Grove Fm., Waubeek Facies, Stone City. a. Stegerhynchus sp., b. Meristina sp., c. Coolinia sp., d. Resserella sp., e. Protathyris sp., f. Spirinella sp. All approx. 2x.

where the upper 32 feet (9.8 m) of the Scotch Grove Formation is accessible. These beds are assigned to the Waubeek Facies and are characterized by dense to vuggy, bedded, non-cherty, sparsely fossil-moldic dolomites. Some vugs are lined with quartz crystals. Fossils include small echinoderm debris molds, bryozoans, brachiopods, cup corals, and Heliolites. Proceed up-section to the broad quarry ledge where the Scotch Grove-Gower contact is exposed. Immediately below the first laminated dolomites of the Gower Formation, the top-most bed of the Waubeek Facies is quite fossiliferous, and brachiopods (Fig. 12) and horn corals can be collected. Proceed up-section into the sequence of laminated Anamosa quarrystone. The lowest interval in the Anamosa Facies is known as the "Gray beds" or "Gray unit" by quarrymen (about 20 ft; 6 m thick). Wavy to stromatolitic laminations are characteristic of this interval, and interbedded "flints" (dense dolomites) are scattered throughout. The laminations are especially stromatolitic in appearance 8 to 11 feet (2.4-3.4 m) above the base of the Gower. A band of brachiopod molds is present about 11 feet (3.4 m) above the base of the Anamosa, and "rods" are scattered throughout the sequence. Large ostracodes (Leperditia) and bivalves (Pterinea) are noted in a single bed. Quarrymen term the 4-foot thick (1.2 m) unit above the "Gray unit" the "Bad Ledge", and Henry (1972) noted strangely laminated rocks, in part cherty, intraclastic, and with evaporite crystal molds, in the "Bad Ledge". Above the "Bad Ledge" the "White unit", a 40-foot (12 m) thick interval of planar laminated to thinly bedded dolomites, in part cherty, is present. "Rods" are present in the upper 5 feet (1.5 m) of the "White unit." The uppermost interval, here termed the "upper unit", is easily accessible up-sequence from the underground mine area ½ mile (0.8 km) east of the Weber Co. office. The "upper unit" consists of porous, vuggy dolomites, in part intraclastic, and obscurely laminated dolomites. The "upper unit" has been previously assigned to either the Wapsipinicon or Gower Formations. The discovery of Leperditia ostracodes in the upper unit suggests inclusion in the Gower Formation. Return to your vehicles. If time permits, we will visit the underground mine area.

42.8 Proceed up road to Anamosa.
43.1 Upper entrance to Weber Quarry.
43.8 Turn right onto E28 blacktop.
46.3 Bridge over Buffalo Creek.
46.5 Enter Anamosa.
46.65 Flashing stop sign; turn right on Elm St.
46.8 Turn left on Hickory St.
46.85 Next right on Mechanics St.
46.9 Eden Golf Carts; quarry behind building is developed in cherty Buck Creek Quarry Facies.
47.0 Intersection at City Park; turn left.
47.1 Bear left.
47.25 City Park Quarry; parking area on left or right side of road.

STOP 6. Anamosa City Park Quarry (SE NE sec. 10, T 84, R 4W, Jones Co.). An old quarry face at this locality exposes a broad mounded structure in the Palisades-Kepler Mound Facies (Fig. 13). The rocks here are generally crinoidal, and crinoidal packstone fabrics are common in the central portions of the mound. Brachiopod and bryozoan debris is present in some beds. Tabulate corals and stromatoporoids are conspicuous in places within the mound. Additionally, nautiloids, colonial and solitary rugose corals, and trilobites are present. The similarities of the rocks at this locality and Stop 1 should be apparent. However, the beds at Stop 6 do not dip at angles as high as those noted at Stop 1. Stop 6 exposes a single mound, unlike the complex of mounds at Stop 1. The lateral facies relations of the Palisades-Kepler mound at Stop 6 are especially significant. The mound grades southward towards Wapsipinicon State Park into flat-lying, skeletal-moldic rocks assigned to the Fawn Creek Facies. To the west, the mound at Stop 6 is abruptly replaced by dense, cherty dolomites of the Buck Creek Quarry Facies (we passed by a nearby exposure at Eden Golf Cart Co.). Therefore, exposures at Stops 1 and 6 demonstrate the lateral equivalence of the Palisades-Kepler Mound Facies and the Buck Creek Quarry Facies.

47.25 Turn around, and go back on the same road.
47.5 Bear right.
47.6 Elm St. intersection; turn left.
47.8 Cross Wapsipinicon River.
47.85 Turn left into Wapsipinicon State Park; bear left along river. Be cautious along the narrow roadway!
48.1 Use parking areas near the latrine. Type locality of the Fawn Creek Facies.

STOP 7. Wapsipinicon State Park exposures (NE SE sec. 10, T 84, R 4W, Jones Co.). This is a state park, and rock hammers or specimen collecting is not permitted. We are only about 1000 feet (300 m) south of the carbonate mound at Locality 6, although the beds at Stop 7 are horizontally-bedded. Otherwise, the rocks are lithologically similar, generally with abundant skeletal molds, and, in places, crinoid-replaced packstones are noted. Crinoid, tabulate coral, and solitary rugose coral remains are prominent. The Fawn Creek Facies occupies the same stratigraphic position as the Buck Creek Quarry and Waubeek Facies. What differences can you note between the rocks here at Wapsi State Park and the other upper Scotch Grove Facies that we visited earlier in the day? What similarities?

END OF TRIP.

Field trip participants may wish to quickly tour the state park and examine the excellent and picturesque series of exposures of the flat-bedded Fawn Creek Facies along the Wapsipinicon River and Dutch Creek. Caves are developed in these rocks (Ice Cave, Horsethief Cave).

It's been a long day, and this marks the official end of the trip. For those of you that can bear the thought of looking at more dolomite outcrops (gag!), there is one more optional field stop where

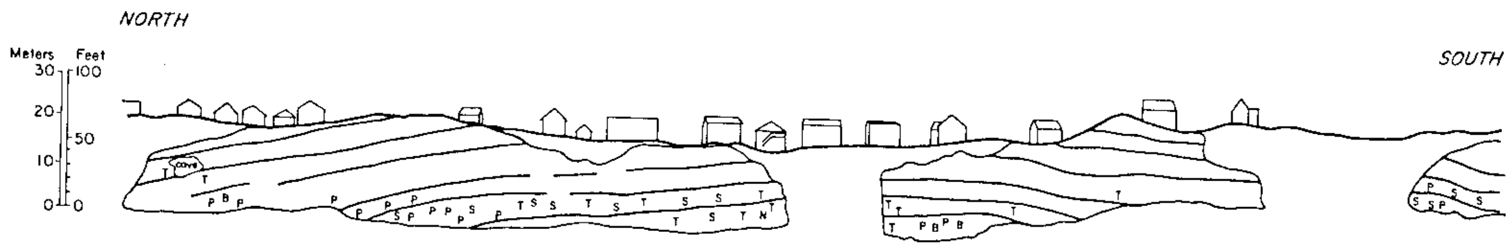

Figure 13. Anamosa City Park, quarry face, Stop 6. Broad mounded structure in the Palisades-Kepler Mound Facies is well exposed. Beds traced from photo-mosaic. T--tabulate corals, S--stromatoporoids, B--bryozoans, N--nautiloids, P--crinoidal packstones.

we will investigate an anomalous Scotch Grove-Gower contact (come on, Brian, give us a break!).

Route to Stop 8 (optional).

48.4 Park entrance; note outcrops of cherty Buck Creek Quarry Facies at park entrance and across the highway in an old quarry (Kray's Junkyard). Turn right and continue on Elm St.
48.9 Turn left on West Main St.
49.1 Turn right on Iowa St.
49.8 Lumberyard and adjacent quarry; Buffalo Creek on left.
51.1 Roadside outcrops; these rocks have characteristics intermediate in character between the Waubeek and Fawn Creek Facies.
51.3 Outcrops.
51.4 Pavement ends; outcrops continue along roadway.
51.8 Old State Penitentiary Quarry on opposite bank of Buffalo Creek. Dimension quarrystone from this locality was utilized to construct the State Penitentiary in Anamosa.
52.0 Good exposure of Waubeek Facies; laminated Anamosa beds upsection and in quarry on opposide of bluff.
52.7 Roadside exposure. Park along edge of road.

STOP 8. Buffalo Creek exposure (NE NE sec. 32, T 85, R 4W, Jones Co.). At previous stops we examined exposures of the Scotch Grove-Gower contact where the contact was sharp. At this locality there is interbedding of Waubeek-like and laminated Anamosa lithologies (Fig. 14). The contact is drawn at the base of the first well-laminated dolomite bed. This outcrop (and a few others) suggests that the uppermost few feet of the Waubeek Facies may be, in part, a lateral facies equivalent of the lowermost few feet of the laminated Anamosa Facies. The Scotch Grove-Gower contact displays 40 feet (12 m) of relief in the vicinity of this outcrop (at the Penitentiary Quarry). It's suggested that as laminated Gower deposition was initiated, remnants of Waubeek environments may have persisted for a short while on topographic highs, interfingering with laminated carbonates. However, the bulk of the laminated Anamosa sequence is not equivalent to the Waubeek Facies, and anomalous interbedding of these facies is only observed in the basal portion of the Gower Formation.

I hope you've had your fill of dolomite by now.

A question in closing: What model of dolomitization best explains the pervasive dolomitization noted in the Silurian of eastern Iowa? Or is more than one model applicable?

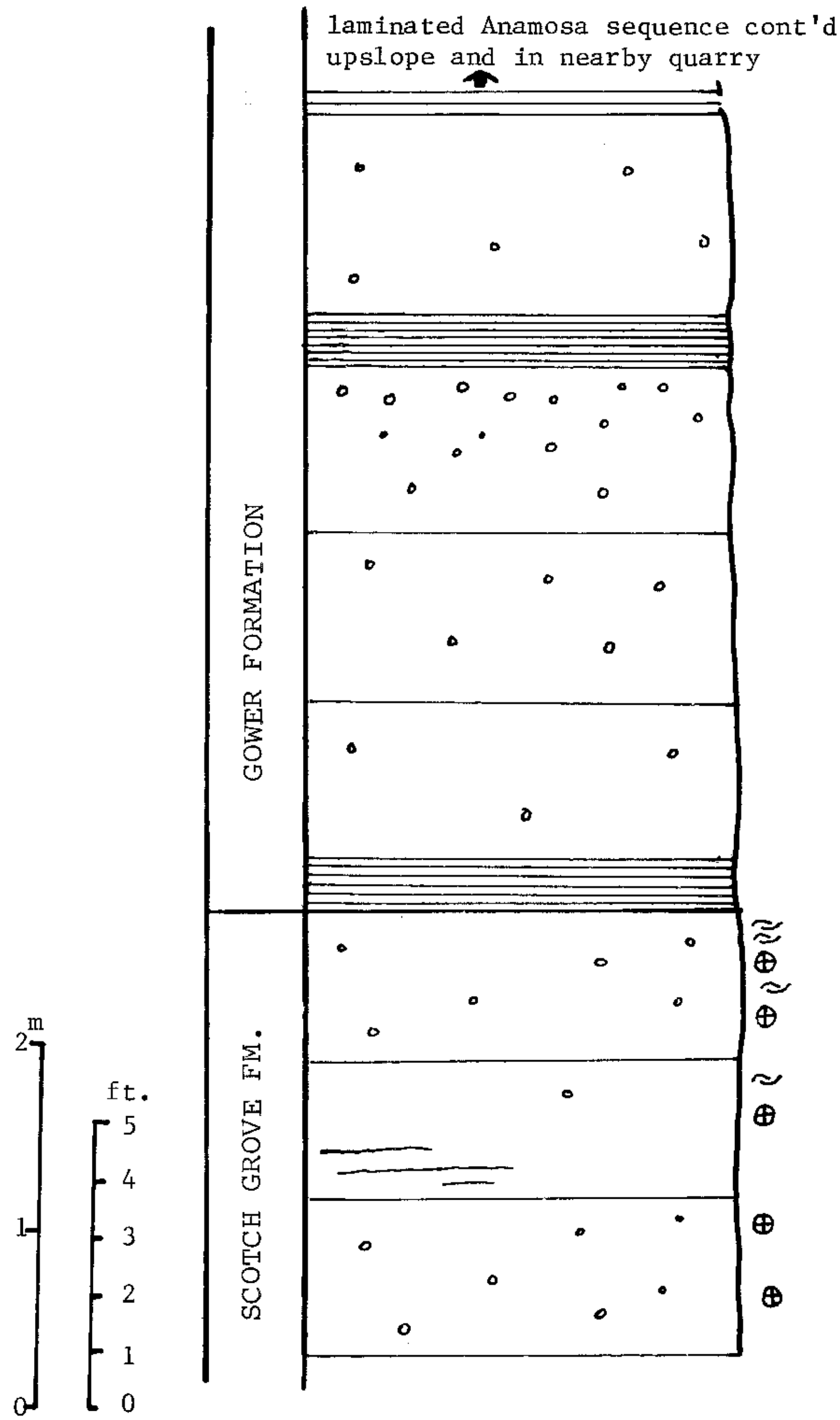

Figure 14. Stratigraphic sequence, Stop 8. Note interbedding of Waubeek-like and laminated Anamosa lithologies in lower portion of Gower Formation.