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Previously divided primarily on the basis of paleontologic units, the approximately 60-80 m thick Hopkinton Dolomite in eastern Iowa also comprises a set of lithologically unique subunits. With the development of a new capability for inter-regional correlation of Lower Silurian strata based on the use of sea-level curves, it is especially appropriate to recognize these subdivisions of the Hopkinton Dolomite as formal member units. Locally, the relationships shown by these units may also contribute to a better understanding of the Plum River Fault Zone and its associated structures in Iowa and Illinois. Willman (1973) named the Sweeney and Marcus Formations for strata in northwestern Illinois that he physically correlated with the *Syringopora* and *Pentamerus* Beds of the lower Hopkinton Dolomite. It is recommended that these units receive wider application as the Sweeney and Marcus Members of the Hopkinton Dolomite. The names Farmers Creek, Picture Rock, Johns Creek Quarry, Welton, and Buck Creek Quarry are proposed as members of the remaining middle to upper Hopkinton Dolomite. These names supersede the *Cyclocrinites*, *Favosites*, Bioherm, *Cyrtia*, and *Pentameroides* Beds, respectively (Johnson, 1975; 1980).

INDEX DESCRIPTORS: Iowa geology, Silurian, Hopkinton Dolomite, Lithostratigraphy

Paleontologic units have served well as informal subdivisions of the Lower Silurian Hopkinton Dolomite in eastern Iowa. Both local and inter-regional considerations, however, now favor the recognition of a more formal lithostratigraphic nomenclature. Emphasis on paleobathymetric data derived from these units (Johnson, 1975; 1980) led to the interpretation of a regional sea-level curve, which subsequently became a standard of comparison in the study of several other regions. The cycles of sea-level fluctuation recorded in the Hopkinton Dolomite also may be detected in the Lower Silurian strata of Michigan and New York (Johnson and Campbell, 1980); Manitoulin Island, Ontario (Johnson, 1981); Anticosti Island, Quebec (Johnson, Cocks, and Copper, 1981); as well as the Bruce Peninsula and Lake Timiskaming areas of Ontario (Colville and Johnson, 1982). These widespread patterns of sea-level change are thought to be similar in magnitude and timing to the third order cycles identified by Vail *et al.* (1977) through seismic studies of post-Paleozoic strata. Careful application of sea-level curves will permit new refinements in the inter-regional correlation of Lower Silurian strata.

Elsewhere, as in the case of the Iowan sections, sub-formational rock units are still informally defined (i.e. Upper and Lower *Pentamerus* Beds of the Schoolcraft Dolomite in Michagan). The purpose of this paper is to propose formal member units for the Hopkinton Dolomite of Iowa. Locally, the thickness and facies relationships shown by these units (in addition to their bathymetric information) also may contribute to a more complete understanding of the Plum River Fault Zone and its associated structures in Iowa and Illinois.

PREVIOUS NOMENCLATURE

Use of paleontological and other informal names for Lower Silurian strata in Iowa has a long history (Fig. 1). Recognizable subunits of the Hopkinton Dolomite were described by Wilson (1895) in both lithological and paleontological terms before the name of the parent formation was designated. With few modifications, these subunits were retained in the reports of Calvin (1896, 1898) and Calvin and Bain (1900). A miscorrelation of pentamerid-bearing beds was probably the reason why they failed to recognize Wilson's Upper Coralline Beds (see Johnson, 1977). The name "Delaware" was initially proposed by Calvin (1896, p. 49) as a geologic formation encompassing all but the top-most Building Stone Beds of Wilson's arrangement. Because this formation name was preoccupied, Calvin (1906, p. 574) eventually settled on the name "Hopkinton," after the town by that name in Delaware County, Iowa. Since then, the Hopkinton Dolomite has lost basal units now assigned to the Mosalem, Tete des Morts, and Blanding Formations, although other units above and including the Upper Quarry Beds have been added on. Willman (1973) formally named the Sweeney and Marcus Formations for strata in northwestern Illinois, which he correlated with the *Syringopora* and *Pentamerus* Beds in Iowa. In his preliminary study, Johnson (1975) still preferred to use most of the old, informal names. He referred to the Upper Quarry or Building Stone Beds as the Bioherm Beds and he added several other paleontologic units (including the problematical *Goniophyllum* and *Callipentamerus* Beds tentatively placed at the top of the Hopkinton Dolomite). Correspondence of newly proposed member names to the old paleontologic units is given in the last column of Fig. 1.

DEFINITIONS

A composite section of Lower Silurian strata in eastern Iowa including lithologic, paleontologic, and bathymetric data is drawn to scale in Fig. 2. The 60-80 m thick Hopkinton Dolomite comformably overlies the Blanding Formation, but disconformably underlies the Gower Formation. Individual rock units within the Hopkinton Dolomite easily can be characterized by their their fossil content, but they are also lithologically unique from underlying and overlying rock units. Coral-bearing layers tend to be very thick bedded, finely to medium crystalline, and highly vuggy. Layers with concentrations of pentamerid brachiopods are usually medium bedded, finely crystalline, and sometimes cherty. Layers associated with stricklandiid brachiopods are medium or poorly bedded, very finely crystalline, often cherty, and richly bioclastic. Repetition of similar lithologies is due to the recurrent nature of depositional environments related to water depth (Fig. 2). Some members include two or three different fossil communities, either in stratigraphic succession or in a facies relationship with one another. Seven members of the Hopkinton Dolomite are defined below.

Sweeney Member

Originally defined as a separate formation by Willman (1973, pp. 36-37) but equivalent to the *Syringopora* Beds, it is recommended that the 9.5-10 m thick rock unit be retained as the basal member of the Hopkinton Dolomite. Lithologically, the Sweeney Member is a tan to brown, very thick bedded, finely crystalline, highly vuggy dolomite. The middle two or three meters tend to be more micritic in texture, with or without scattered zones of white chert nodules, and much less vuggy. Paleontologically, the Sweeney Member typically contains abundant, tabulate coral colonies which are generally silicified. A concentrated zone of the brachiopod *Stricklandia lens progressa* (see Johnson, 1980, Table 6) often occurs in the middle of the member.

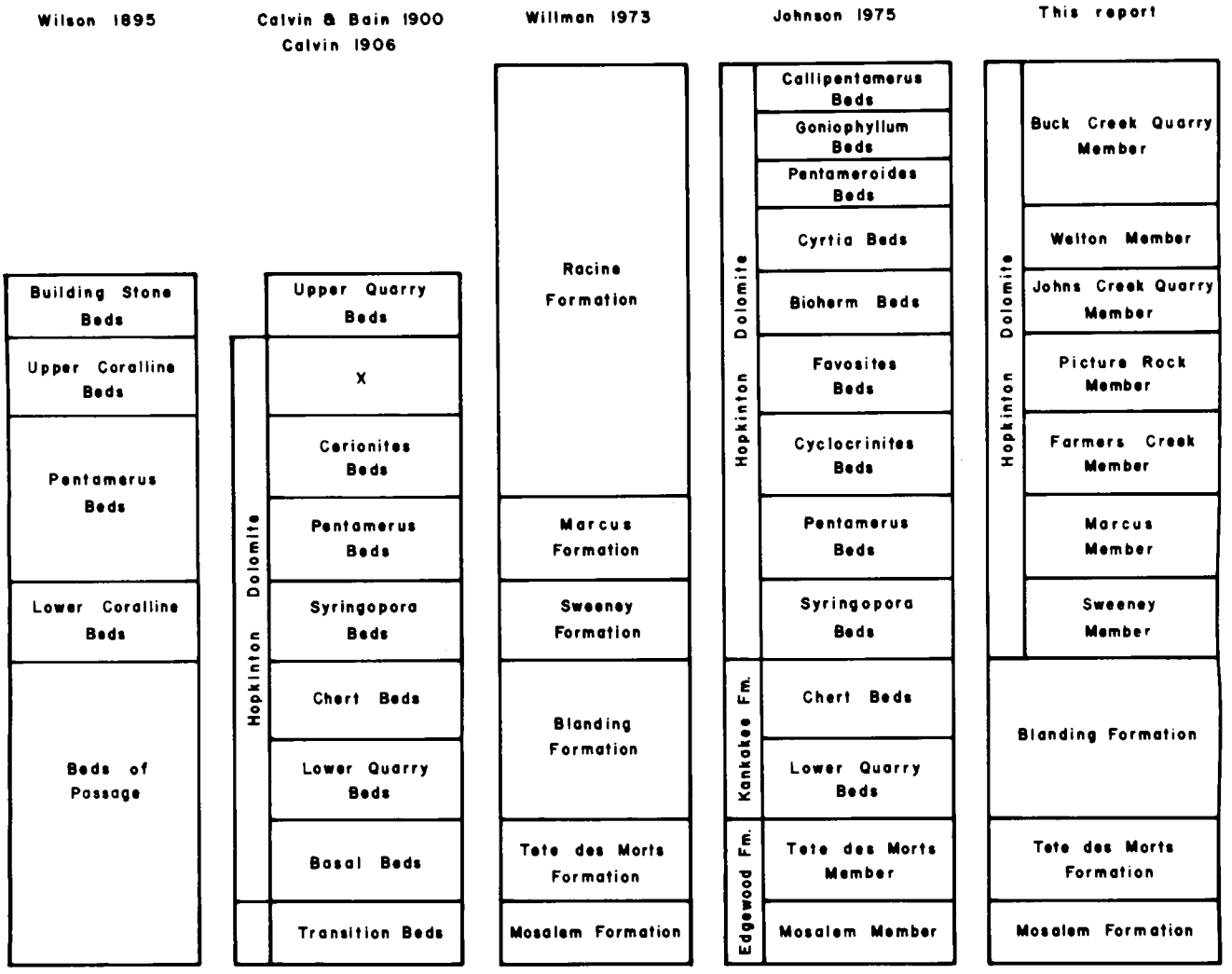

Fig. 1. Development of nomenclature for rock units attributed to or related to the Hopkinton Dolomite (Lower Silurian of eastern Iowa).

This dates the unit as Early Fronian (C_1 or C_2) in age (Johnson, 1979). The type locality of the Sweeney is listed by Willman (1973, p. 53) as the Palisades Park North Section in Carroll County, Illinois. A good supplementary reference section in Iowa can be found at the road cut on U.S. Highway 151 just north of the Dubuque Municipal Airport in Dubuque County (locality 64: N½ Sec. 22, T88N, R2E).

Marcus Member

Named by Willman (1973, pp. 37-38) as a separate formation largely correlative with the *Pentamerus* Beds, it is recommended that the 8.5-9 m thick rock unit be redefined and down-graded to member status in the Hopkinton Dolomite. Lithologically, the Marcus Member is a tan, medium bedded, finely crystalline dolomite with a few horizons of scattered gray-white chert nodules usually placed toward the middle of the unit. Often preserved in growth position, the brachiopod *Pentamerus oblongus* is abundant (see Johnson, 1980, Table 4) throughout. The top 0.5-1 m of the member is characteristically formed by a distinctive coquina of *Pentamerus* valves. Rare specimens of *Stricklandia lens progressa* are sometimes present at the base of the member. Based on the advanced development of the stricklandiids, the age of the Marcus Member is Late Fronian (C_2 or C_3). Willman (1973, p. 53) designated the Palasades Park Old Quarry Section in Carroll County, Illinois as the type locality of the Marcus. As originally defined in Illinois, *Pentamerus oblongus* is most abundantly found in the "lower 5 to 15 feet" of the unit (William, 1973, p. 37). The contact with the overlying Racine Formation is not well defined. It is possible that part of the "*Cyclocrinites* Beds" was included by Willman in his Marcus Formation. Unfortunately, the type locality is largely overgrown. A more suitable reference section fully accessible in Iowa is locality 28 (Fig. 3): the Meloy Quarry located 1.5 km north of Bernard in Dubuque County (SW¼ NW¼ Sec. 23, T87N, R1E).

Farmers Creek Member

The name Farmers Creek is here proposed for the 12 m thick unit corresponding to the *Cyclocrinites* Beds of the Hopkinton Dolomite. Lithologically, this member is a tan, massive, very finely crystalline to micritic dolomite. Paleontologically, the upper two-thirds of the Farmers Creek Member is dominated by the abundant pentamerid brachiopod *Harpidium maquoketa* (see Johnson, 1980, Table 4.) The dasycladacean green alga *Cyclocrinites* (= *Cerionites*) *dactioloides* occurs sporadically throughout the entire unit. Up to 4.5 m of the basal portion of the Farmers Creek Member tends to be unevenly thick to very thick bedded and the brachiopod *Sticklandia laevis* (= *lens ultima*)

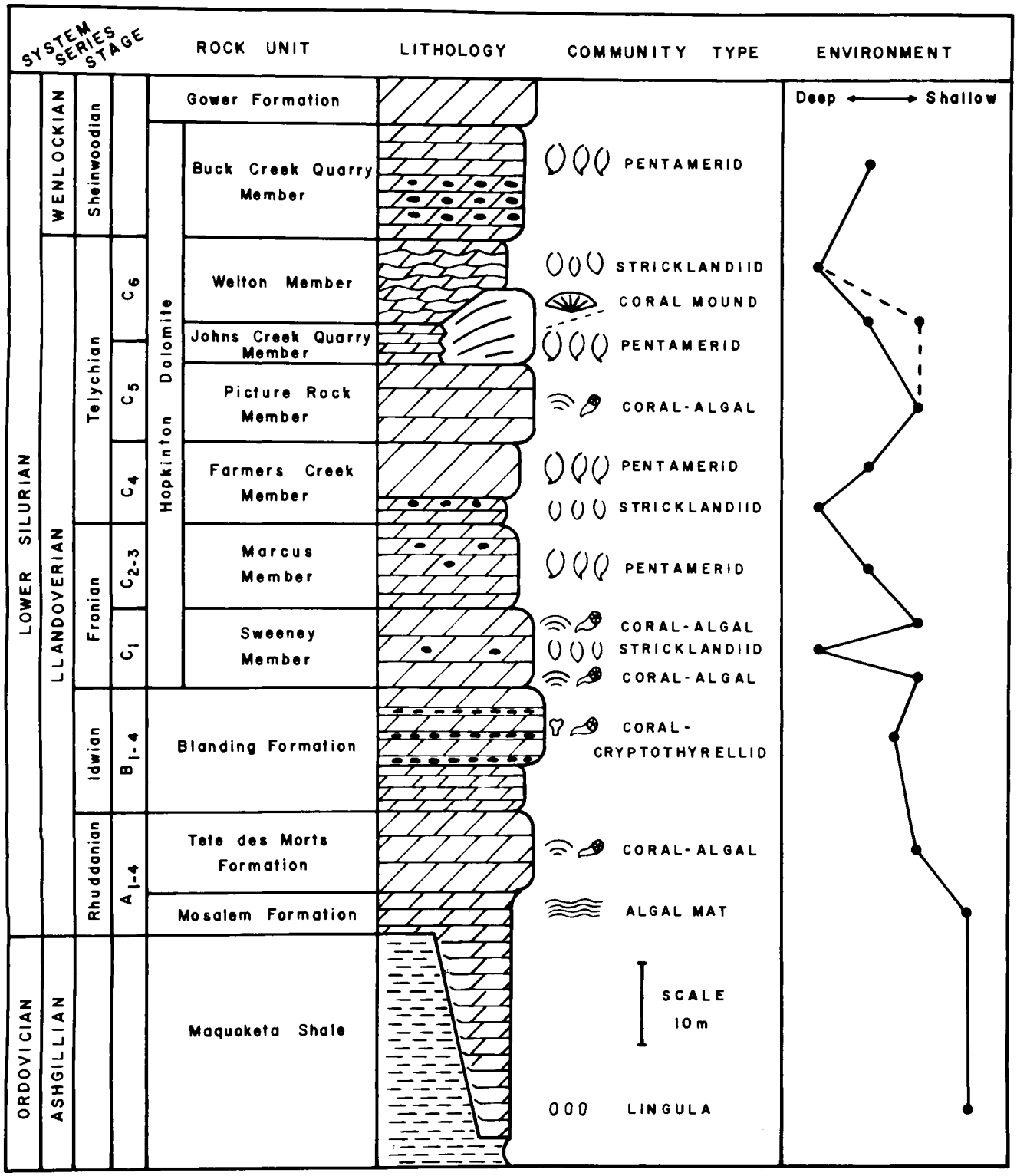

Fig. 2. Composite section of Lower Silurian strata in eastern Iowa, featuring new member units of the Hopkinton Dolomite.

is commonly present (see Johnson, 1980, Table 5). This horizon was mistakenly first assigned to the underlying *Pentamerus* Beds by Johnson (1975, p. 136). The presence of *Stricklandia laevis* dates the Farmers Creek Member as Early Telychian (C_4 or C_5) in age (Johnson, 1979). Farmers Creek Township in Jackson County, Iowa lends the member its name. The type section is a complete and fully accessible exposure of the member at locality 102 (Fig. 3): Schwenker Quarry located near the center of Farmers Creek Township, 4.75 km west to northwest of Fulton (NE¼ SW¼ Sec. 16, T85N, R2E). Other exposures appear widely throughout eastern Iowa (Fig. 3, localities 28, 48, 73, 88, 90, 115), and may also be traced to northwestern Illinois (Fig. 3, locality 70).

Picture Rock Member

Formerly called the *Favosites* Beds, the name Picture Rock is here proposed for the member unit stratigraphically succeeding the Farmers Creek Member. With a variable thickness between 5-11.5 m, the Picture Rock Member is a tan to brown, very thick bedded or sometimes massive, medium crystalline, highly vuggy dolomite. Paleontologically, the rock unit typically contains abundant, tabulate coral colonies (see Johnson, 1980, Table 1). In contrast to the much alike Sweeney Member, the corals preserved in this rock unit are generally not silicified. Often a horizon of *Pentamerus oblongus* may be found at the very base of the Picture Rock Member. The advanced condition of the outer plates in these *Pentamerus* suggests a Middle Telychian (C_4 or probably C_5) age for the Picture Rock Member (Johnson, 1979). Variation in unit thickness may be linked with the development of anticlinal and synclinal structures closely related to the Plum River Fault Zone (see following discussion). Natural bluffs along the Maquoketa River running through Picture Rock Park in Jones County, Iowa offer a fully accessible type section of the member (locality 90: SE¼ SW¼ Sec. 32, T86N, R2W). At its type locality, the unit is between 10.75-11.50 m thick. The Picture Rock Member is exposed in many other localities in eastern Iowa (Fig. 3, localities

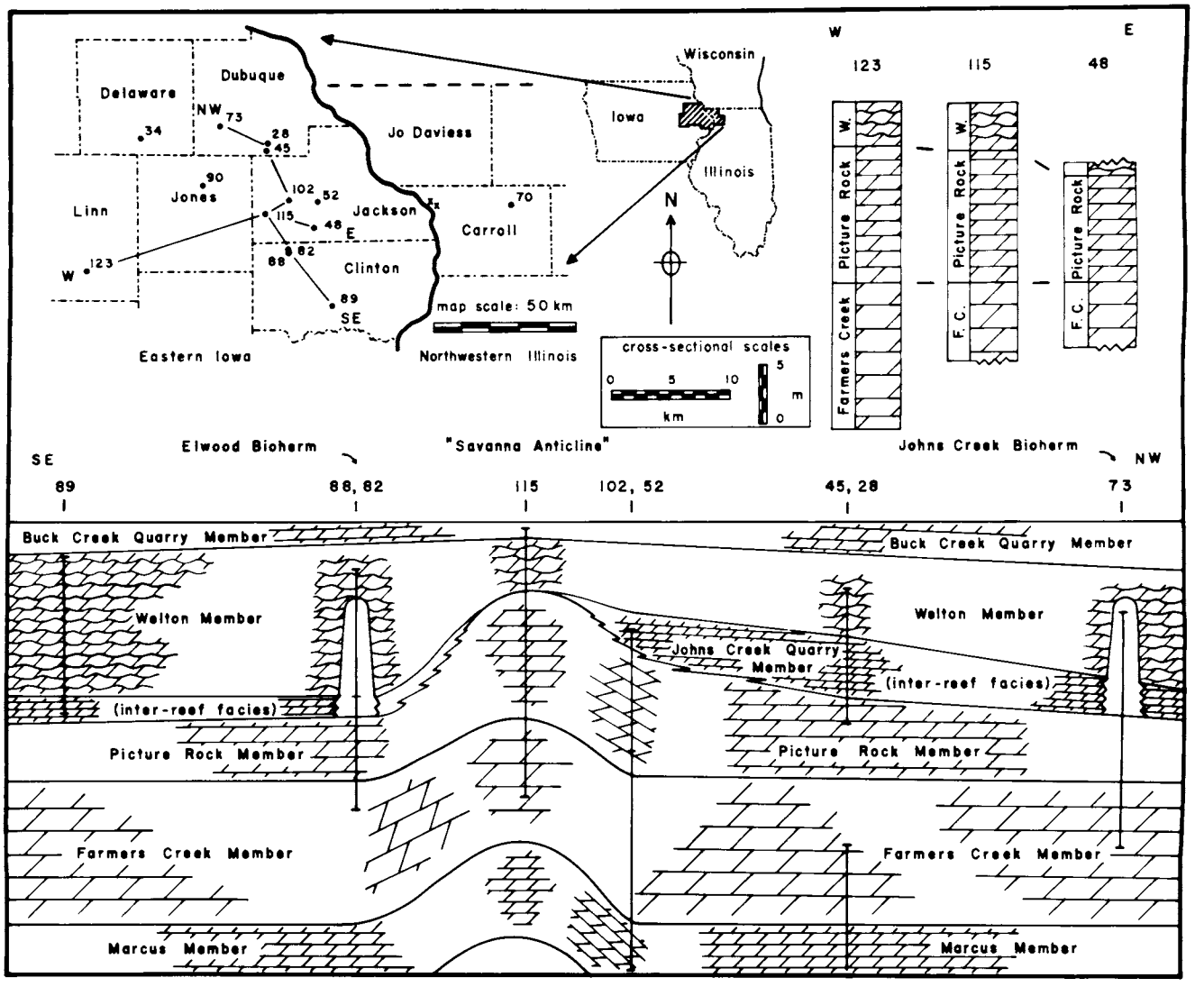

Fig. 3. Location map and stratigraphic cross-sections of the Hopkinton Dolomite across the "Savanna Anticline" in eastern Iowa. The X's marked in Carroll County, Illinois show the location of the Sweeney and Marcus type sections designated by Willman (1973); the numbered localities marked in Iowa include type sections for the Farmers Creek, Picture Rock, Johns Creek Quarry, Welton, and Buck Creek Quarry Members of the Hopkinton Dolomite (see text). Vertical bars below numbered localities represent the hard data on which the cross-sectional interpretation is based. Consult the appendix for more detailed locality descriptions.

45, 48, 52, 73, 88, 102, and 115).

Johns Creek Quarry Member

Johns Creek Quarry is the name proposed here for the member unit which stratigraphically succeeds the Picture Rock Member. Previously called the Bioherm Beds, two facies with distinctly different lithologies and fossil content are involved. There is a patch-reef facies and an inter-reef facies. Lithologically, the reef mounds are composed of tan, massive, micritic textured dolomite up to 7-10 m in thickness. Upright coral colonies of *Syringopora* sp. 2 m high (Philcox, 1970, Fig. 2) and large fragments of *Diphyphyllum* sp. form the framework of the reef mounds. Generally only 3-5 m in thickness, the inter-reef facies is lithologically composed of cream to tan, evenly medium bedded, finely crystalline dolomite. Common at some localities is the brachiopod *Pentameroides subrectus*; less common are the brachiopod *Costistricklandia* (= *Plicostricklandia*) *castellana* and crinoid *Petalocrinus mirabilis* (see Johnson, 1980, Table 3). Occurrence of a weakly ribbed *C. castellana* in the inter-reef facies suggests a Late Telychian (C_5 or C_6) age for the Johns Creek Quarry Member (Johnson, 1979). The type locality is Johns Creek Quarry, where the relationship between the patch-reef and inter-reef facies is clearly shown (see Johnson, 1980, Fig. 6). Designated as locality 73 (Fig. 3), the quarry is 6.5 km south of Farley in Dubuque County, Iowa (SE¼ SW¼ Sec. 36, T88N, R2W). Philcox (1970) has described other localities in eastern Iowa where the bioherms occur.

Welton Member

The name Welton is here proposed for the member unit formerly referred to as the *Cyrtia* Beds. Layers typical of the Welton Member are found stratigraphically in place above both the patch-reef and inter-reef facies of the Johns Creek Quarry member. For example, the Welton Member drapes the bioherms at localities 73 and 82 and it blankets the inter-reef beds at localities 45, 88, and 89 (Fig. 3). Up to 12.5 m or more in thickness, this rock unit is lithologically composed of tan, poorly bedded, very finely crystalline dolomite. Paleontologically, the Welton Member preserves a high diversity stricklandiid or "*Clorinda*" community including *Costistricklandia* (= *Plicostricklandia*) *castellana* and many other brachiopods, crinoids, trilobites, and bryozoans (see Johnson, 1980, Table 6). Based on the presence of *C. castellana*, the rock unit's age is probably C_6 Late Telychian (Boucot and Ehlers, 1963). Although a good section showing the upper contact with the overlying member has still not been discovered, chertified *Pentameroides* characteristic of the Buck Creek Quarry Member have been observed in geest deposits above the truncated bioherms of the Johns Creek Quarry Member and associated beds of the Welton Member at localities 73 and 103. The thickest known exposure of the Welton Member is exposed in Behr Quarry (locality 89, Fig. 3), and thus is the best choice for a type section. Locality 89 is situated 5 km south of Welton in Clinton County, Iowa (NW¼ SW¼ Sec. 2, T81N, R3E).

Buck Creek Quarry Member

In place of the *Pentameroides* Beds, as well as the problematical *Goniophyllum* and *Callipentamerus* Beds, the name Buck Creek Quarry is here proposed for the stratigraphically top-most member of the Hopkinton Dolomite. Lithologically, this rock unit is a mottled gray to light brown, thick bedded to massive, finely crystalline dolomite with numerous white chert horizons. Abundant throughout most of the Buck Creek Quarry Member is the brachiopod *Pentameroides subrectus*; less common are the brachiopod *Costistricklandia* (= *Plicostricklandia*) *multilirata* and rugose coral *Porpites* sp. Apparently restricted to the top horizon of the member is the brachiopod *Callipentamerus corrugatus* (locality 115, Fig. 3). Collectively, these fossils indicate a Late Telychian (C_6) to Sheinwoodian age (Boucot and Ehlers, 1963; Boucot, 1964). Located on the east edge of the Village of Buck Creek in Delaware County, Iowa (NE¼ NW¼ Sec. 20, T87N, R4W) the Buck Creek Quarry provides the member's type section. This quarry (locality 34, Fig. 3) features a 16.5 m thick exposure of the rock unit. The lower contact with the underlying Welton Member has not yet been discovered in outcrop, but a good upper contact with the overlying Gower Formation may be found in the bluffs of the Maquoketa River's South Fork (locality 115).

DISCUSSION

Structural features are known to have influenced reef development. Smoot (1958) documented the relationship of Silurian reef structures to pre-existing Ordovician anticlines in south-central Illinois. By comparison the so-called "Savanna Anticline" in eastern Iowa is poorly understood. An investigation by Kolata and Buschbach (1976) concluded that faulting accounts for the principle feature of the lineament, which they renamed the Plum River Fault Zone. Their work focused on the Illinois side of the Mississippi River and resulted in the identification of some smaller structures located adjacent to the fault zone. These include the Uptons Cave Syncline, Forreston Dome, Brookville Dome, and Leaf River Anticline (in Carroll and Ogle Counties). Graben type block faulting seems to have taken place in post-Silurian time, but followed a line of pre-existing domes and anticlines (Kolata and Bushbach, 1976, Fig. 5).

Stratigraphic work in Iowa shows that the Picture Rock Member of the Hopkinton Dolomite is about twice as thick near the strike of the lineament as it is further to the north or south (Fig. 3). While coral patch-reefs grew atop the Picture Rock Member to the north or south (Fig. 3, localities 73 and 82), the biostromal Picture Rock Member may have continued deposition near the lineament of the future Plum River Fault Zone (Fig. 3, localities 48, 115, and 123). One interpretation is that a related line of domes and anticlines began to form during Middle to Late Telychian time, coeval with an episode of rising sea level. Bioherms (Johns Creek Quarry Member) formed in response to deepening waters, but corals and stromatoporoids of the flattened, shallow-water morphology (Picture Rock Member) continued to thrive along the growing crest of the minor uplifts. Where very thick, the upper part of the Picture Rock Member may hence be a facies of the Johns Creek Quarry Member. Predictably, the inter-reef facies of the Johns Creek Quarry Member pinches out as it approaches the Plum River Fault Zone (Fig. 3). The lineament is capped, however, by layers of fine crinoidal debris characteristic of the Welton Member.

Evidence of structural folding is not necessarily restricted to the area immediately adjacent to the Plum River Fault Zone. The Brookville Dome in Illinois, for example, is located about 13 km south of the fault zone (Kolata and Buschbach, 1976, Fig. 4). Similarly offset domes probably occur in Iowa, as well. To the north of the Plum River Fault Zone in Iowa, the Picture Rock Member of the Hopkinton Dolomite is very thick in its type section (locality 90, Fig. 3). It is still capped, however, by inter-reef facies and a small bioherm (1.75 m in height) belonging to the Johns Creek Quarry Member.

CONCLUSIONS

Surface expression of the Hopkinton Dolomite's member units together with the bathymetric interpretaion of their depositional environments offers new insight on the possible temporal development of structural features associated with the Plum River Fault Zone. Subsurface exploration of these units may help to better define the size and relationship of structural folds linked with the Plum River Fault Zone in eastern Iowa. The naming and definition of member units belonging to the Hopkinton Dolomite also contributes to the clarity of inter-regional correlations regarding Lower Silurian strata. Other regions, such as nothern Michigan and the Manitoulin Island of Ontario, possess Silurian "coral" and "*Pentamerus*" beds. Recognition

of all such units in formal lithological terms will help to avoid confusion in the new refinements of time-rock correlation brought about by the use of sea-level curves.

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APPENDIX: LOCALITY DESCRIPTIONS

28. MELOY QUARRY: operational quarry (Wendling-Industrial Management, Inc.) 1.5 km north of Bernard on Dubuque County Road Y-31; SW¼ NW¼ Sec. 23, T87N, R1E, Dubuque County, Iowa.

34. BUCK CREEK QUARRY: abandoned quarry at the east edge of the Village of Buck Creek; NE¼ NW¼ Sec. 20, T87N, R4W, Delaware County, Iowa.

45. McDEVITT QUARRY: abandoned quarry 1.5 km south of Bernard on Dubuque County Road Y-31; NW¼ SE¼ Sec. 34, T87N, R1E, Dubuque County, Iowa.

48. FROST QUARRY: abandoned quarry 2.5 km east of Maquoketa; SW¼ SE¼ Sec. 16, T84N, R3E, Jackson County Iowa.

52. ANDREW QUARRY: operational quarry (B. L. Anderson, Inc.) 2.5 km west of Andrew; Cen. NW¼ Sec. 24, T85N, R3E, Jackson County, Iowa.

64. KEY WEST ESCARPMENT: road exposure on U.S. Highway 151, 3.75 km south to southwest of Key West; N½ Sec. 22, T88N, R2E, Dubuque County, Iowa.

70. NESEMEIER QUARRY: abandoned quarry 3 km north of Lanark on Illinois Highway 72; SW¼ SE¼ Sec. 20, T25N, R6E, Carroll County, Illinois.

73. JOHNS CREEK QUARRY: operational quarry (Wendling Industrial Management, Inc.) 6.5 km south of Farley on Dubuque County Road Y-13; SE¼ SW¼ Sec. 36, T88N, R2W, Dubuque County, Iowa.

82. ELWOOD QUARRY: operational quarry (Alpha Crushed Stone) 3 km north of Elwood; Cen. NW¼ Sec. 24, T86N, R4W, Clinton County, Iowa.

88. WIRTH QUARRY: abandoned quarry 1.5 km northwest of Elwood; NW¼ NE¼ Sec. 17, T83N, R2E, Clinton County, Iowa.

89 BEHR QUARRY: operational quarry (Alpha Crushed Stone) 5 km south of Welton; NW¼ SW¼ Sec. 2, T81N, R3E, Clinton County, Iowa.

90. PICTURE ROCK PARK BLUFFS: exposures along the west bank of the Maquoketa River in Picture Rock Park; SE¼ SW¼ Sec. 32, T86N, R2W, Jones County, Iowa.

102. SCHWENKER QUARRY: operational quarry (B. L. Anderson, Inc.) 4.75 km west to northwest of Fulton; NE¼ SW¼ Sec. 16, T85N, R2E, Jackson County, Iowa.

103 MONTICELLO QUARRY: operational quarry (B. L. Anderson, Inc.) 4.75 km west of Monticello on Jones County Road D-62; NW¼ NW¼ Sec. 24, T86N, R4W, Jones County, Iowa.

115. MAQUOKETA RIVER (South Fork) BLUFFS: exposures on the south bank and road exposure up the hill from the south bank, 4.75 km north of Baldwin; NE¼ NE¼ Sec. 3, T84N, R1E, Jackson County, Iowa.

123. SOUTH CEDAR RAPIDS QUARRY: operational quarry (Martin Marietta Aggregates) directly across the Cedar River from the Palisades Keplar State Park; NE¼ NW¼ Sec. 15, T82N, R6W, Linn County, Iowa. This section is based on drill core information.

Willman (1973) locality descriptions

27. PALISADES PARK NORTH SECTION: Mississippi River bluff 0.1 mile northwest of intersection of Illinois Highway 84 with roads to campground and boat ramp, Mississippi Palisades State Park; NE¼ SW¼ Sec. 21, T25N, R3E, Carroll County, Illinois.

28. PALISADES PARK OLD QUARRY SECTION: abandoned and largely overgrown quarry in Mississippi Palisades State Park, just north of the south boundary, 0.5 miles north of Savanna-Sabula bridge; SE¼ SE¼ Sec. 33, T25N, R3E, Carroll County, Illinois.