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In eastern Iowa, the Llandovery Series (Lower Silurian) consists of the Edgewood and Kankakee formations as well as much of the Hopkinton Dolomite. Outcrops of these rocks provide fossil assemblages of marine benthic invertebrates well suited for reconstructing epeiric sea communities. Results of preliminary field studies in Dubuque, Jackson, Jones, and Delaware counties indicate that an initial *Lingula* Community at the base of the section is succeeded by recurrent patterns of Coral, Pentamerid, and Stricklandid communities. The patterns are interpreted as community response to fluctuations in sea level, estimated to vary between a few and 60 m. At least two repetitions of deepening to shallowing seas are represented, possibly linked to eustatic causes. The orderly sequence of communities, symmetric with respect to reversals in changing water depth, suggests that the local geologic record is reasonably complete. Beds of the Hopkinton Dolomite previously unrecognized as distinct units are described and the first occurrences of the brachiopods, *Cyrtia* and *Ferganella,* from the Lower Silurian of Iowa are reported.
INDEX DESCRIPTORS: Community Patterns; Sea Level Fluctuations; Silurian, Llandovery Series, of Iowa.

During the early part of the Silurian Period, epeiric seas submerged extensive regions of the Canadian, Baltic, and Siberian continental shields. Widespread, generally transgressive conditions may have been caused by eustatic fluctuations in sea level linked to the melting of late Ordovician and early Silurian glaciers (Berry and Boucot, 1972, 1973a and 1973b). Fossil assemblages representing depth-associated communities of marine benthic invertebrates provide a means for the detection and relative measurement of ancient sea level fluctuations. A synchronous change in communities over great distances suggests fluctuations on a global scale, whether due to climatic events or other causes. Conversely, restricted instances of change in communities may reflect regional fluctuations due to localized diastrophic causes.

This paper reports on preliminary field studies of the Llandovery Series (Lower Silurian) in eastern Iowa, and is intended to demonstrate the suitability of the contituent fossil assemblages for community reconstruction. Preservation of recurrent community patterns is interpreted as a local record of depth changes in the epeiric seas which had inundated the North American craton. Correlation with community successions recorded in other areas is discussed and, as a topic of more detailed study, may indicate the extent and nature of sea level fluctuations which occurred during early Silurian times.

COMMUNITY APPROACH

Whittaker (1970) defines a community as a system of organisms living together and linked together by their effects on one another and their shared responses to the environment. The benthic communities reconstructed by Ziegler (1965) from the Llandovery Series of Wales and the Welsh Borderland include *Lingula, Eocoelia,* Pentamerid, Stricklandid, and *Clorinda* communities, listed in order of increasing distance from shore. Different lines of evidence indicate that these communities are depth-associated. When plotted on paleogeographic maps, the communities occur in bands parallel to the ancient shoreline. Especially convincing are localized instances of submarine volcanic flows. When they buried deeper water communities, the flows prepared the way for subsequent colonization of shallower water communities by reducing the height of the water column. Although the community name is derived from the most characteristic member, Ziegler, Cocks, and Bambach (1968) quantitatively defined the communities on the basis of entire, distinctive faunas. Some members are restricted to a single community, while others have a broader environmental tolerance and occur in several communities.

Since the initial work on Llandovery communities, others from regions including the East Baltic states, New York State, and Nevada have been studied in detail, as reviewed by Ziegler and Sheehan (1974). Each of these areas was situated near a continental margin where the slope of the sea floor was sufficient to accommodate several different communities contemporaneously. Those communities near land (Wales, New York) received an influx of clastic sediments. A zoogeographic survey of North America for the Llandovery Epoch (Ziegler and Boucot, 1970) shows that Iowan communities were located in the remote center of the submerged craton, 1,300 to 1,400 km from the nearest shelf margin. The depositional environment in which these communities lived consisted of carbonate sediments, almost to the exclusion of clastic sediments. Development of a platform-like sea bottom over eastern Iowa apparently supported only a single ubiquitous community at a time. Contemporaneous facies, if present, existed in such widely spaced belts as not to be obvious in this particular region. The result was to make shifts in community regime a contingency of fluctuating sea level. Iowan reconstructions include *Lingula,* Coral, Pentamerid, and Stricklandid communities. With few exceptions, the platform communities are similar in faunal composition to counterparts established for continental margin areas. The conformity may provide the opportunity to relate carbonate lithologies to communities previously known mostly in the context of clastic sediments.

The terminology applied to Welsh communities by Ziegler (1965) was permitted to correspond with the nomenclature of chronological genera. Thus the *Stricklandia* Community

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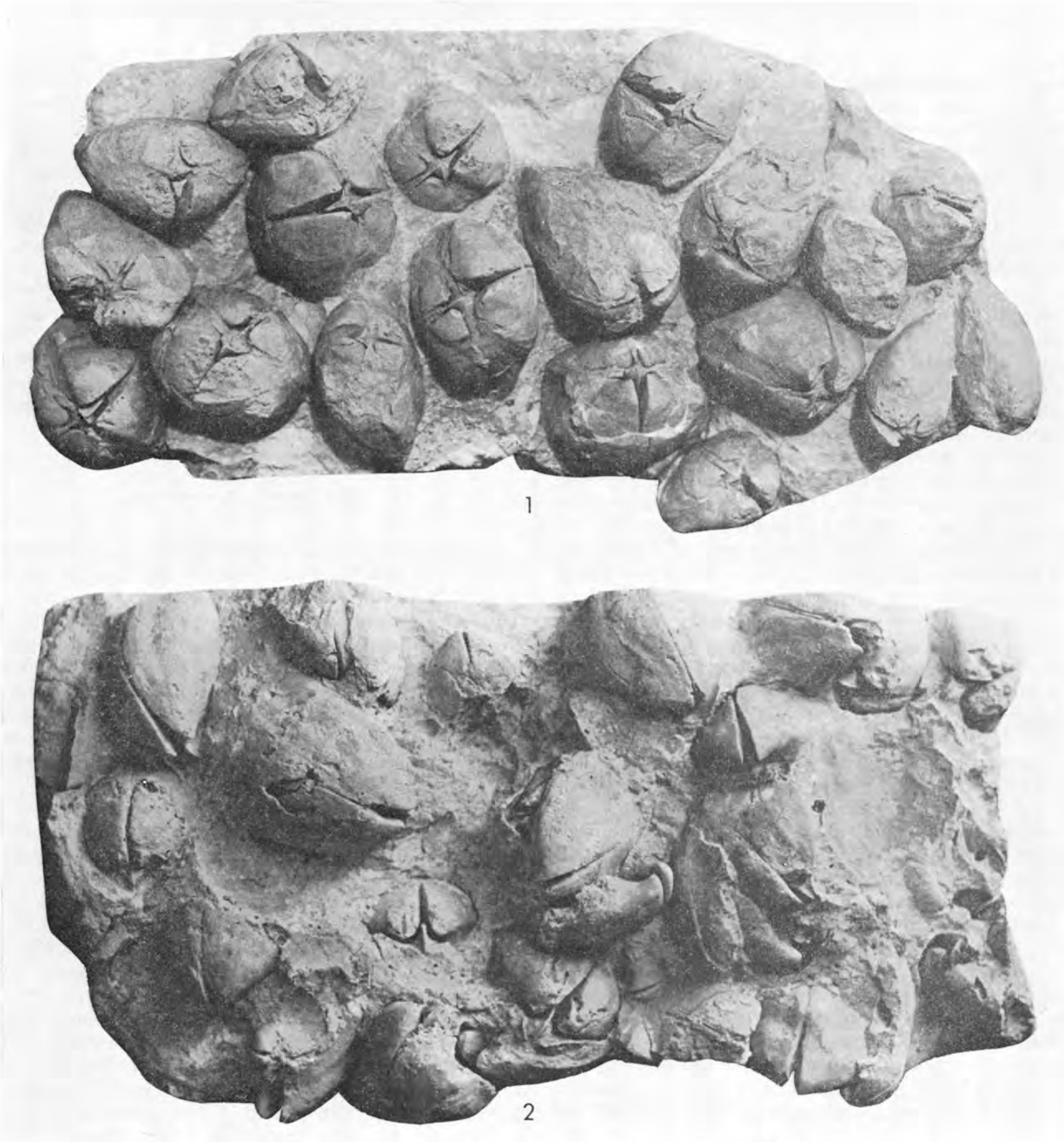

Plate 1. Figures 1, 2. Basal view of contrasting bedding planes from the *Pentamerus* Beds of the Hopkinton Dolomite. 1. Articulated valves (internal molds) of *Pentamerus oblongus* (Sowerby) preserved in life position. 2. Scattered valves (internal molds) of the same species disarticulated after death. The blocks were collected at the B. L. Anderson Maquoketa Quarry located 1.5 km north of Maquoketa in Jackson County (NE¼ NE¼ Sec. 13, T84N, R2E) from horizons 20 cm and 60 cm, respectively, above the base of the *Pentamerus* Beds. Both figures, ½X.

has as a successor the *Costistricklandia* Community, although community composition remains virtually unchanged. Comparable genera in North America are known as *Microcardinalia* and *Plicostricklandia* (Boucot and Ehlers, 1963). In this paper terminology will be restricted to avoid proliferation of community names. The term Stricklandid Community will be applied to assemblages in which any form of stricklandid brachiopod is a common element. Likewise, the term Pentamerid Community will be used for assemblages in which any form of pentamerid brachiopod is a predominant element.

RECONSTRUCTING IOWAN COMMUNITIES

Current usage by the Iowa Geological Survey designates the Edgewood, Kankakee, Hopkinton, and Gower formations as the primary rock stratigraphic units of Silurian age in Iowa. The Llandovery Series is considered to include the first two of these as well as most of the Hopkinton Dolomite. During the summer of 1974, rocks of this series were studied in an outcrop area extending across much of Dubuque, Jackson, Jones, and Delaware counties in eastern Iowa. Interpretation of temporal events as represented by the strata of this region depends critically on the recognition of benthic communities. Johnson (1964) lists three categories of evidence for the identification of ancient communities: (1) field evidence of burial *in situ*, (2) taxonomic analogy with a modern community, and (3) recognition of recurring suites of species analogous to the recurrence observed among modern communities.

Life orientations, particularly those of pentamerid and stricklandid brachiopods, can frequently be observed in vertical cross-section at the outcrops. The undersides of two contrasting bedding planes from the *Pentamerus* Beds of the Hopkinton Dolomite are illustrated in Plate 1. The first slab (Figure 1) shows 19 articulated specimens of *Pentamerus oblongus* preserved in life position. The second slab (Figure 2) shows an accumulation of scattered but relatively unfragmented valves of the same species. Such occurrences are not limited to any specific horizon in the *Pentamerus* Beds. Even immature, oriented specimens, numbering about 50 per square decimeter, are sometimes preserved in a growth stage moderately advanced beyond their spat fall. The stricklandid brachiopod, *Microcardinalia*, also occurs in life position at a particular horizon in the *Pentamerus* Beds. Oriented specimens of *Pentameroides subrectus* can often be observed in the younger *Pentameroides* Beds of the same formation.

The preservation of brachiopods in life position has been documented by Ziegler, Boucot, and Sheldon (1966), who cite occurrences of pentamerid brachiopods from Alabama and stricklandid brachiopods from Scotland. Rudwick (1970, p. 89) develops the explanation that the characteristic orientation is the result of weight stabilization due to differential thickening of the shell in the umbo region. An analogy is drawn to a weighted toy figure which, when displaced, automatically rights itself. For brachiopods such as *Pentamerus*, coping with ontogenetic atrophy of the pedicle, weight stabilization may have been the remedy to the problem of orientation. It should be pointed out, however, that the same orientation could have been arrived at as a function of efficient packing. Thus, surrounding neighbors would help prop up a brachiopod on its umbo simply to achieve utilization of maximum space available to the colony. Orientation by such a method seems a more natural event for immature individuals still possessing functional pedicles.

Despite the thorough dolomitization of the strata in Iowa, internal molds of the Lower Silurian organisms are commonly preserved in fine detail. Even in beds where life orientations are not readily apparent, the faunal associations show few signs of post-mortem disassociation and fragmentation of shells. Among brachiopods of this age, tooth and socket hinges were not well developed for articulation of the valves. The muscle systems were the primary agents for holding the valves together. Unlike the tough resilium of pelecypods, disintegration of the brachiopod tissues after death permitted rapid disarticulation of the shells. Since the ratio of articulated to disarticulated shells is usually quite high at a given horizon, burial must have been swift.

Faunal associations are found to be recurrent, especially in the Hopkinton Dolomite. Stratigraphic control is by reference to phyletic modifications in stricklandid brachiopods. The brachiopods occur at several horizons in the Hopkinton Dolomite, and include forms of *Microcardinalia* sp., *Plicostricklandia castellana*, and *P. multilirata*. Differences most readily observable in hand specimens involve a progressive increase in number of plications, beginning from a smooth shell, and a progressive enlargement of the adductor muscle scar. Berry and Boucot (1970, p. 163) date Iowan occurrences as C_1-C_5, C_6, and Wenlock, respectively. On this basis, deposition of the Hopkinton Dolomite is considered to have spanned the late Llandovery Epoch and continued into the Wenlock Epoch. Evidence of *in situ* burial coupled with the recurrent nature of faunal associations permits reconstruction of communities, as far as members with preservable hard parts are concerned.

HISTORICAL PERSPECTIVE

A gap of 75 years has elapsed since a comprehensive program of research has focused on the stratigraphic paleontology of the area in which the Llandovery Series outcrops in Iowa. The region was first geologically surveyed by D. D. Owen (1840 and 1844), later scrutinized by James Hall and J. D. Whitney (1858), and during the late 1800's and early 1900's drew the attention of several investigators, none as devoted as Samuel Calvin (1896; 1898; Calvin and Bain, 1900; and 1906). Hinman (1968, p. 8) provides a detailed summary of the historical development of Silurian nomenclature in Iowa.

From descriptions and plates in Owen's report of 1844, there can be no doubt that he observed the Chert Beds of the Kankakee Formation and the *Syringopora*, *Pentamerus*, and *Cyclocrinites* Beds of the Hopkinton Dolomite (see Figure 1). These he called the Coralline Beds of the Magnesian Cliff Limestone, properly correlating them with the British Silurian of Murchison (1839). Hall and Whitney (1858), followed by White (1870), did little to subdivide the Silurian of Iowa. For the most part it was simply referred to as the Niagaran limestone strata. By the turn of the century, numerous quarry operations across the Silurian cuesta had been opened for dimension stone and to supply lime kilns. These artificial exposures greatly facilitated expanded study, and A. G. Wilson (1895) became the first to attempt a subdivision of the older Niagaran strata. The system devised by Calvin was developed in its greatest detail for the report on the geology of Dubuque County (co-authored with Bain, 1900, p. 445). His scheme, shown in Figure 1, had Transition Beds of the Maquoketa Shale (now recognized as the lower Edgewood Formation) succeeded by the Basal Beds, Lower Quarry Beds, Chert Beds, *Syringopora* Beds, *Pentamerus* Beds, *Cerionites* (= *Cyclocrinites*) Beds, and finally the Upper Quarry Beds. The entire sequence came to be called the Hopkinton Limestone after the town by that name in Delaware County (Calvin, 1906). The divisions are clearly discernible today, although the stratigraphy is flawed by an error in correlation. Calvin equated the occurrence of *Pentamerus oblongus* from his *Pentamerus* Beds with that of *Pentameroides subrectus* from younger strata. A significant difference between the two genera is that the plates of the brachial valve

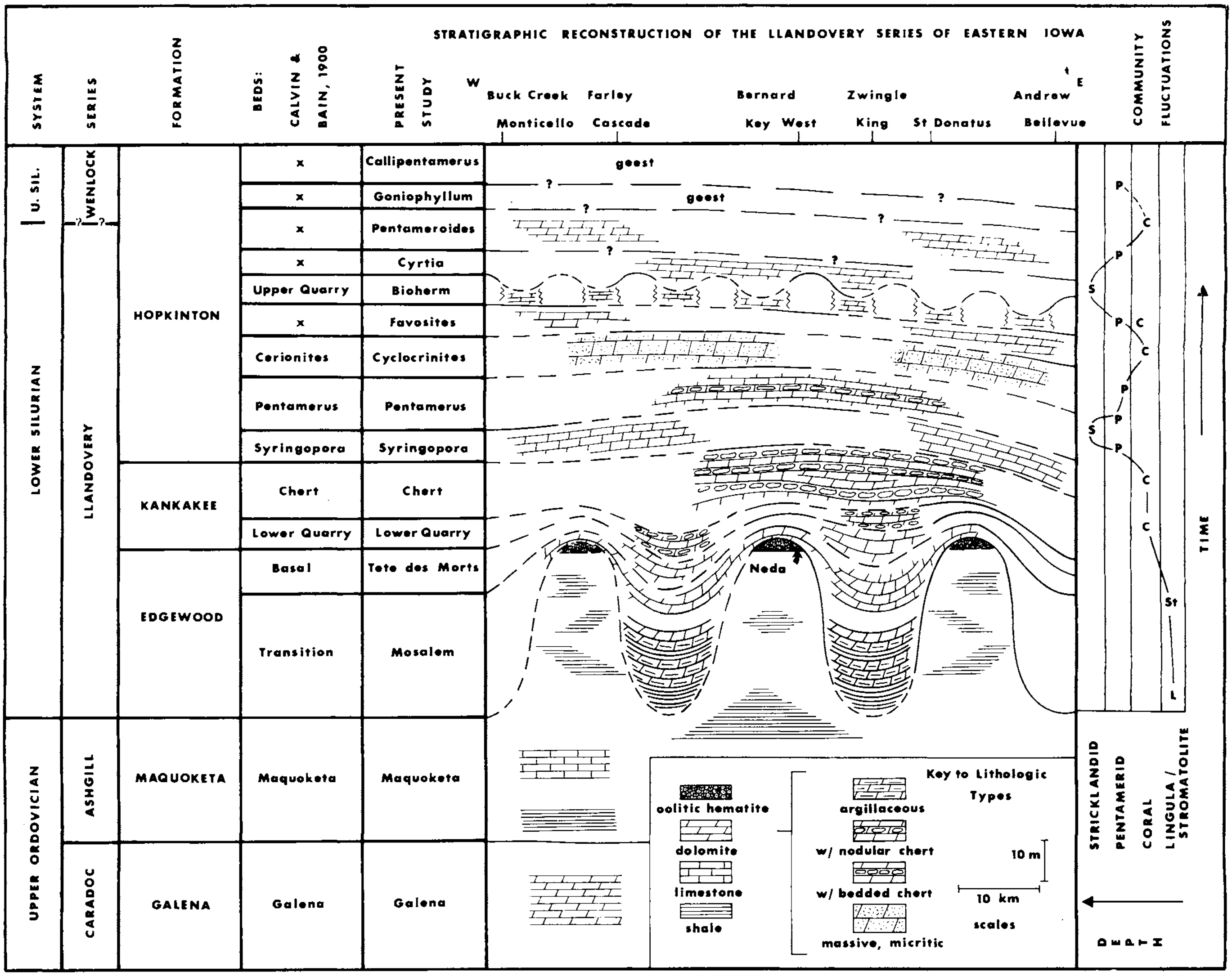

Figure 1. Stratigraphic reconstruction of the Llandovery Series in eastern Iowa, depicting a broad, east-west trending profile across the Silurian escarpment and cuesta. Outcrop evidence for rock stratigraphic contacts is indicated by solid lines. Short dashed lines represent a confident extension of known relationships. Conjectured contacts are shown by long dashed lines.

in *Pentamerus* remain distinct, but fuse in *Pentameroides* (Plate 2, Figures 6 and 7 respectively). Calvin's judgment may have been influenced by the original description of Hall (1894, p. 238) making the later genus a variety of the species *Pentamerus oblongus*. Regardless, the error caused Calvin to exclude several distinctive beds from his stratigraphy. He was perplexed that faunas succeeding what he thought 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.

Later workers revised some of the nomenclature applied by Calvin. Scobey (1935) extended recognition of the Edgewood and Kankakee formations from Illinois to Iowa, thereby restricting the Hopkinton Dolomite to the interval from the base of the *Syringopora* Beds to the base of the Gower Formation. Brown and Whitlow (1960), in mapping the rocks of the Dubuque South Quadrangle, subdivided the Edgewood Formation into a lower Mosalem Member and upper Tete des Morts Member. They found that the Edgewood Formation varies greatly in thickness from locality to locality, as regulated by the underlying Maquoketa Shale. Where the Edgewood Formation is thick, the Maquoketa Shale below is thin, and the converse. Cause of the relationship was determined to be an erosional surface carved into the Ordovician Maquoketa Shale, creating shale hills subsequently filled in by deposition of the Silurian Edgewood Formation. Highly consistent data from the subsurface of Iowa (Agnew, 1955, Figures 4 and 5) show oolitic hematite of the Neda Iron Ore to be capping summits of the shale hills. The iron ore has been assigned to the Maquoketa Shale as the Neda Member on the basis of Ordovician fossils cited by Savage and C. S. Ross (1906, p. 191). Although the description states that the fossils show few signs of abrasion, the possibility exists that the oolites were precipitated as a consequence of shoaling action during earliest Silurian times.

Many authors have studied individual taxa from the rich faunas of the Hopkinton Dolomite, particularly during the last decade. Unique occurrences from selected beds have never been placed within a stratigraphic framework tight enough to enable full comparison with other events which took place during the deposition of the Hopkinton Dolomite. The establishment of such a framework for the whole of the Llandovery Series as represented in eastern Iowa is prerequisite to the interpretation of environmental changes spanning the epoch.

INTERPRETATION OF STRATIGRAPHIC SECTIONS

The stratigraphic reconstruction drawn in Figure 1 depicts a broad profile trending westward from the Mississippi River Valley across the Silurian escarpment and cuesta of Iowa. Although no single locality provides a continuous section incorporating each of the units involved, several different localities expose overlapping sequences. A total of more than 40 outcrop sections examined in Dubuque, Jackson, Jones, and Delaware counties add to the framework upon which interpretation is based.

Edgewood Formation

Mosalem Member and Tete des Morts Member

Age: C. A. Ross (1964) states that diplograptid graptolites from the base of the Edgewood Formation in Iowa are similar to those in Illinois, which Berry and Boucot (1970, p. 145) consider indicative of an early Llandovery age within zones 16-19 of the British graptolite succession.

Lithologies: At localities of varying extremes in thickness, the wavy, thin-bedded, argillaceous dolomite of the lower Mosalem Member can be readily distinguished from the medium grained, massive bedded, vuggy dolomite of the Tete des Morts Member.

Faunas: Diplograptid graptolites occur near the base of the Mosalem Member at a locality where the section is thick. At about this horizon, lingulid and rhynchonellid brachiopods also occur. Stromatolites can be observed near the base of the section, at a locality where the Mosalem Member is very thin. The fauna of the Tete des Morts Member consists predominantly of favositid corals.

Communities: The Mosalem Member contains a fauna suggestive of a *Lingula* Community, while the Tete des Morts Member contains remnants of a Coral Community.

Interpretation: Erosion of the Maquoketa Shale before the close of the Ordovician Period resulted in the development of regional relief. This event may have been induced by the glaciation of the large land mass, Gondwanaland, a portion of which included parts of present day Africa and South America. Resumption of marine conditions during the deposition of the Edgewood Formation led to the drowning of topographic relief. The argillaceous nature of the dolomite in the lower part of the Mosalem Member can be attributed directly to erosion of the shale hills. As the valleys were filled in, the supply of clastic sediments decreased. Replacement of the *Lingula* Community by stromatolites and a Coral Community may have been brought about by a rise in sea level or perhaps nothing more than elimination of the clastic sediment source.

Reference: Thick sections of both members of the Edgewood Formation, bracketed by the Maquoketa Shale below and the Kankakee Formation above, can be observed at the Bellevue State Park in Jackson County (NE¼ NW¼ Sec. 19, T88N, R5E). There the total thickness is about 33 m, with lingulid and rhynchonellid brachiopods first appearing about 3 m above the base of the Mosalem Member. Much thinner sections of both members, totaling 3.75 m, occur at the road cut near the interchange of U.S. highways 151 and 61 in Dubuque County (NW¼ NW¼ Sec. 23, T88N, R2E). There a stromatolite horizon at the base of the Mosalem Member is 35 cm thick.

Kankakee Formation

Lower Quarry Beds and Chert Beds

Age: If there is no evidence of an unconformity at either contact, as previous workers claim (Brown and Whitlow, 1960, p. 40; Scobey, 1938, pp. 215-216), then stratigraphic position above the Edgewood Formation and below the Hopkinton Dolomite suggests a middle Llandovery age for the Kankakee Formation.

Lithologies: The Lower Quarry Beds are distinguished by fine grained, evenly stratified dolomite with nodular chert in the upper part. Succeeding the Lower Quarry Beds, the more conspicuous Chert Beds consist of layered, porcelaneous chert interbedded with dense, fine grained dolomite.

Faunas: Trilobites, cup corals, and orthid brachiopods have been observed from the Lower Quarry Beds. The alternating lithologies of the Chert Beds, however, seem to yield different faunas. The dolomite layers contain silicified *Favosites*, while the chert layers contain gastropods, cup corals, and possibly cryptothyrellid brachiopods.

Community: For the most part, the faunas of the Kankakee Formation suggest variations of a Coral Community.

Interpretation: It is not certain to what degree the two faunas of the Chert Beds are mutually exclusive, but the pattern of secondary cherts might be explained as penecontemporaneous replacement selective for a particular kind of shell deposit.

Reference: Bracketed by the Edgewood Formation below and the Hopkinton Dolomite above, an exposure totaling 16 m occurs at the road cut on U.S. Highway 52 near King in Dubuque County (NW¼ SE¼ Sec. 27, T88N, R3E). The Lower Quarry Beds account for only about 3 m of the basal section. Contact of the Kankakee Formation with the overlying Hopkinton Dolomite is marked by a 5 cm thick shale layer about 0.5 m above the uppermost chert layer.

Hopkinton Dolomite

Syringopora Beds

Age: Deposition of the *Syringopora* Beds probably took place at the beginning of late Llandovery time. Willman (1973, p. 37) reports the stricklandid brachiopod, *Microcardinalia*, from a rock unit in northwestern Illinois which he considers equivalent to the *Syringopora* Beds.

Lithology: The strata are formed of massive bedded, somewhat vuggy dolomite with shale partings.

Fauna: The fauna is decidedly coral dominated, notably by *Syringopora tenella, Halysites catenulatus,* and *Favosites favosus.*

Community: There can be no doubt that the fauna represents a distinct Coral Community.

Interpretation: By this time, the sea bottom had become platform-like with little trace of topographic relief. Seas remained very shallow.

Reference: A full representation of the *Syringopora* Beds, succeeding the Kankakee Formation and preceding the *Pentam-*

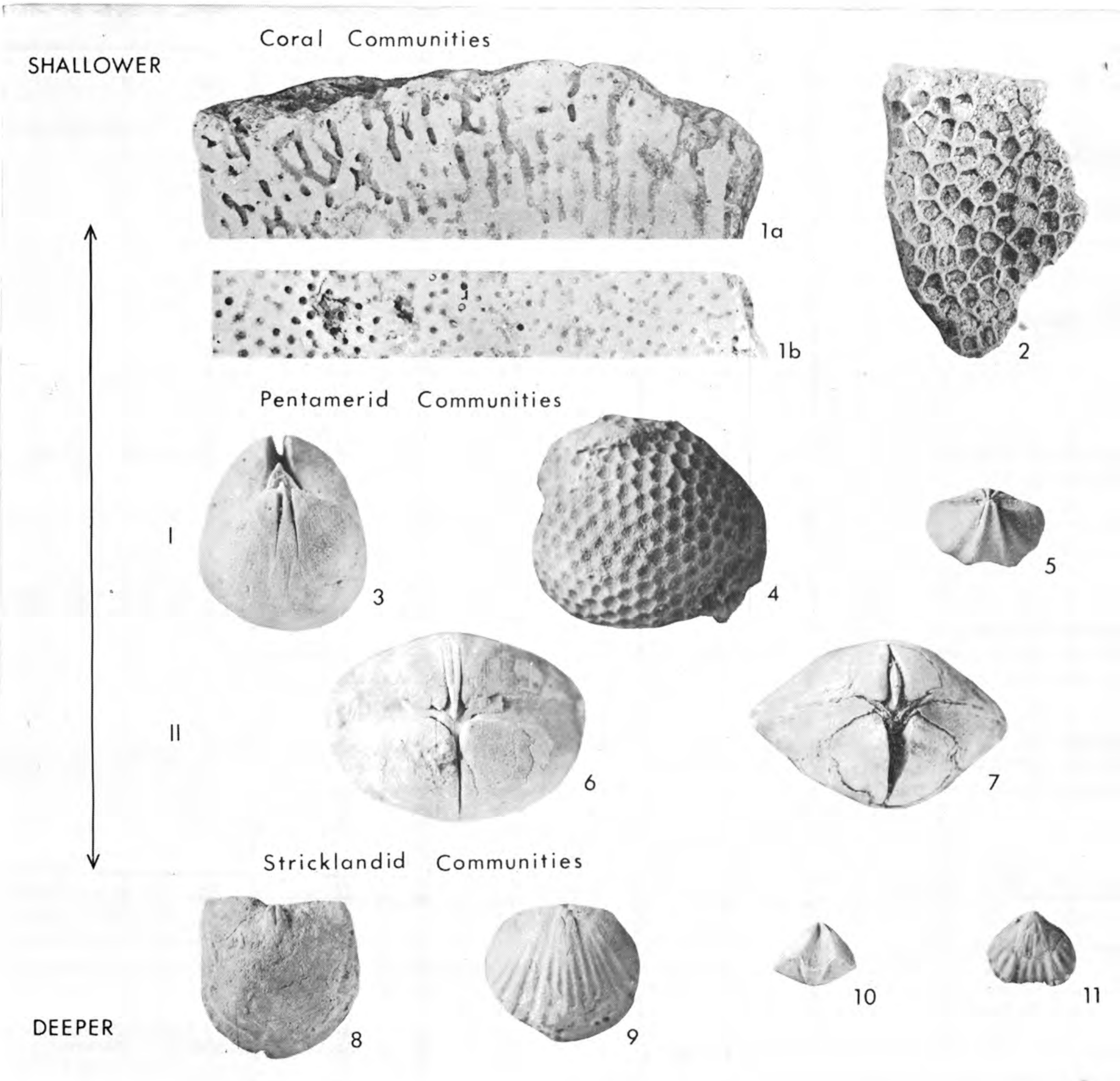

Plate 2. Some diagnostic community elements from the Hopkinton Dolomite. Figures 1, 2. From the *Favosites* Beds. la. Lateral view of *Syringopora* sp. lb. Basal view of the same. 2. *Favosites favosus* (Goldfuss). Figures 3-5. From the *Cyclocrinites* Beds. 3. Brachial view of "*Pentamerus oblongus* var. *maquoketa*" Hall and Clarke. 4. *Cyclocrinites dactioloides* (Owen). 5. *Howellella crispa* (Hissinger). Figure 6. From the *Pentamerus* Beds, *Pentamerus oblongus* (Sowerby). Figure 7. From the *Pentameroides* Beds, *Pentameroides subrectus* (Hall and Clarke). Figure 8. From the *Pentamerus* Beds, brachial view of *Microcardinalia* sp. Figures 9-11. From the *Cyrtia* Beds. 9. Brachial valve of *Plicostricklandia castellana* (White). 10. *Cyrtia exporrecta* (Wahlenberg). 11. *Ferganella* sp. All figures 1X.

erus Beds, can be seen in the road cut on U.S. Highway 151 just north of the Dubuque Municipal Airport in Dubuque County (N½ Sec. 22, T88N, R2E). Total thickness is 9.75 m. The corals are usually replaced by silica. Scattered occurrences of *Microcardinalia* sp. can be found in a zone from 4.5 to 7.75 m above the base of the *Syringopora* Beds.

Pentamerus Beds

Age: Microcardinalia sp., at a horizon in the upper part of the *Pentamerus* Beds, is restricted to a C_1-C_5 date reference but probably represents only the earlier part of the late Llandovery Epoch.

Lithology: The strata are formed of medium bedded dolomite with a cherty zone toward the middle of the section.

Faunas: Beds are crowded by the internal molds of *Pentamerus oblongus* (Plate 2, Figure 6), frequently preserved in life position. Occasionally the brachiopods are associated with such corals as *Halysites catenulatus, Favosites favosus, Cannopora annulata,* and *Heliolites interstinctus.* At the top of the *Pentamerus* Beds, the stricklandid brachiopod, *Microcardinalia* sp. (Plate 2, Figure 8), is predominant.

Communities: Two different communities are indicated, a Pentamerid Community and a Stricklandid Community.

Interpretation: The distinctive, *in situ* faunas of the *Pentamerus* Beds, following that of the *Syringopora* Beds, represent a succession of Coral, Pentamerid, and Stricklandid communities. By analogy to the depth associated communities of sloping continental margins, the early deposition of the Hopkinton Dolomite recorded a central deepening of the water column on the craton. Because the *Microcardinalia* horizon is superseded by beds again containing Pentamerid brachiopods, the rise in sea level must have peaked at a depth compatible to the Stricklandid Community.

Reference: A complete 11.5 m section of the *Pentamerus* Beds, bracketed by the *Syringopora* Beds below and *Cyclocrinites* Beds above, is exposed in the Meloy Quarry 1.5 km north of Bernard on Dubuque County road Y-31 (SE¼ NE¼ Sec. 22, T87N, R1E). Toward the middle of the section, individual beds contain much chert, and from these layers weather delicately silicified specimens of corals and shelled *Pentamerus.* The horizon of *Microcardinalia* is 1.5 m thick, and caps the *Pentamerus* beds. At the locality near the Dubuque Airport, described previously, the lower part of the section can be readily examined. The upper reaches of the unit are most accessible at the Zwingle road cut on U.S. Highway 61 near the intersection with Iowa Highway 246 in Dubuque County (SW¼ SW¼ Sec. 36, T87N, R2E).

Cyclocrinites Beds

Age: A different occurrence of *Microcardinalia* sp. is restricted to the same C_1-C_5 date reference, but because of superposition indicates a slightly younger age for the *Cyclocrinites* Beds.

Lithology: Micritic dolomite with a massive, unbedded appearance is characteristic of the *Cyclocrinites* Beds.

Fauna: Nitecki (1970, 1972) has determined that *Cyclocrinites dactioloides* (Plate 2, Figure 4) belongs to the family Dasycladacea of green algae. The distinctive brachiopod presently known as *"Pentamerus oblongus* var. *maquoketa"* (Plate 2, Figure 3) occurs abundantly in the *Cyclocrinites* Beds and is listed in Berry and Boucot (1970, p. 163) as a yet undescribed new genus and species, *Carmanella maquoketa.* Examples of the associated fauna include the genera *Straparollus, Platyceras, Murchisonia,* and other gastropods; *Ambonychia* and other pelecypods; *Hexameroceras, Kionoceras,* and other nautiloids; *Caryocrinites* and other echinoderms; and *Howellella* (Plate 2, Figure 5), *Platystrophia, Atrypa, Microcardinalia,* and other brachiopods.

Community: The assemblage is considered to represent a shallow Pentamerid Community on the basis of *Howellella,* often an element in the *Eocoelia* Community of continental margin areas, and the abundance of *"Pentamerus oblongus* var. *maquoketa."*

Interpretation: Lithologically the dolomite of the unit is micritic, presumably due to algal contribution to the sediment composition (Blatt, Middleton, and Murry, 1972, pp. 424-425). Massively bedded, the original layering was perhaps obscured by burrowing. The algae may have provided a rich food source for the large molluscan fauna. In the absence of the micritic lithology at other horizons in the Hopkinton Dolomite, the molluscan fauna is much depleted and bedding tends to be well preserved.

Reference: Delimited by the *Pentamerus* Beds below and *Favosites* Beds above, the complete section of the *Cyclocrinites* Beds totaling 9.5 m occurs in the Farmer's Lime Quarry located 3 km northeast of Monticello on U.S. Highway 151 in Jones County (NE¼ NE¼ Sec. 14, T86N, R3W).

Favosites Beds

Age: Stratigraphic position between horizons bearing occurrences of different stricklandid brachiopods dated C_1-C_5 and C_6, respectively, suggests a mid-late Llandovery age for the *Favosites* Beds.

Lithology: Both Calvin (1896, p. 71, p. 76) and Savage (1906, pp. 618-619) mentioned but failed to appreciate the lateral continuity of outcrops here designated as the *Favosites* Beds. The unit is composed of thick bedded, medium grained, vuggy dolomite.

Fauna: The fauna is dominated by corals, mostly *Favosites favosus* (Plate 2, Figure 2), although others such as *Syringopora* sp. (Plate 2, Figure 1) are represented.

Community: The fauna implies a Coral Community.

Interpretation: In succeeding the peculiar Pentamerid Community of the *Cyclocrinites* Beds, the repetition of a Coral Community indicates a resumption of shallower water conditions.

Reference: The 5.75 m thickness of the *Favosites* Beds, bracketed by the *Cyclocrinites* Beds below and Bioherm Beds above, is well exposed in the Martin Quarries 8 km northwest of Cascade on Iowa Highway 136 in Dubuque County (SE¼ NE¼ Sec. 16, T87N, R2W). In contrast to other coral beds, specimens are usually unsilicified.

Bioherm Beds

Age: Dated C_6, the presence of *Plicostricklandia castellana* in the interreef facies gives the Bioherm Beds an age approaching the close of late Llandovery time.

Lithology: Philcox (1970) documented the presence of coral bioherms in the Hopkinton Dolomite. Laterally time equivalent, the Upper Quarry Beds of Calvin are the interreef facies. The term Bioherm Beds is extended to include both phases. Lithologically the interreef facies consists of fine grained, regularly layered beds. According to Philcox, the bioherms include a core of unbedded, micritic dolomite, covered and flanked by coarse crinoidal debris.

Fauna: As Calvin noted (1898, p. 151), his Upper Quarry Beds sometimes yielded a variety of pentamerid brachiopod. The brachiopod is *Pentameroides. Plicostricklandia castellana* can be found as well. Springoperid corals appear to form a large component of the bioherms.

Communities: Although sparse, the fauna of the interreef facies indicates a Pentamerid Community. At the same time, the coral mounds described by Philcox represent a Coral Community. Syringoperid corals appear to form a large component of the bioherms.

Interpretation: As water depth started to increase following deposition of the *Favosites* Beds, coral mounds began to develop, keeping pace with the rising sea level. The habitat region between these mounds supported a deeper water Pentamerid Community.

Reference: Relationship of the coral bioherms of Philcox and the Upper Quarry Beds of Calvin is well demonstrated in the John Creek Quarry about 6.5 km south of Farley on Dubuque County road Y-13 (SE¼ SW¼ Sec. 36, T88N, R2W). Succeeding the *Favosites* Beds and preceding the *Cyrtia* Beds, the entire section of the interreef facies amounts to about 3 m. Comparable strata exposed in an abandoned quarry 2.5 km south of Fulton on U.S. Highway 61 in Jackson County (SW¼ SE¼ Sec. 25, T85N, R2E) yield specimens of *Pentameroides* and *Plicostricklandia* near the base.

Cyrtia Beds

Age: The occurrence of *Plicostricklandia castellana* from the *Cyrtia* Beds is also dated C_6, although superposition with respect to the Bioherm Beds indicates a slightly younger age, nearer the close of late Llandovery time.

Lithology: Recognized in part by Philcox (1970 p. 970), the strata of the *Cyrtia* Beds consist of fine grained dolomite, but are extremely fossiliferous, expecially in contrast with the underlying interreef facies of the Bioherm Beds.

Fauna: The fauna is dominated by brachiopods such as *Plicostricklandia castellana* (Plate 2, Figure 9), *Cyrtia exporrecta* (Plate 2, Figure 10), *Ferganella* sp. (Plate 2, Figure 11), *Eospirifer radiatus,* and *Leptaena rhomboidalis,* but also includes the calyxes of *Marsoupiocrinus* and other crinoids, as well as abundant bryozoans. Neither *Cyrtia* nor *Ferganella* has been reported previously from the Lower Silurian of Iowa. The unit is named the *Cyrtia* Beds because of the common occurrence and distinctive features of that brachiopod.

Community: Faunal composition of the *Cyrtia* Beds is marginal between a Stricklandid and *Clorinda* Community, but lacking the *Clorinda* element, is more like the former.

Interpretation: The deeper water Stricklandid Community marks a peak in the renewal of sea level rise.

Reference: As much as 5.75 m of the *Cyrtia* Beds rest above the Bioherm Beds at the John Creek Quarry.

Pentameroides Beds

Age: A late most Llandovery to Wenlock age may be assigned to *Plicostricklandia multilirata.* However, the occurrence of this brachiopod in the *Pentameroides* Beds, together with what appears to be a species of the coral *Porpites,* suggests that the age of the unit is restricted to the close of late Llandovery time.

Lithology: These are the beds which Calvin miscorrelated with the *Pentamerus* Beds, and properly should be called the *Pentameroides* Beds. The strata consist of fine grained dolomite, often cherty in places.

Fauna: Upper horizons are particularly crowded with the internal molds of *Pentameroides subrectus* (Plate 2, Figure 7), frequently preserved in life position. Much less abundant are specimens of *Plicostricklandia multilirata* and possibly the coral *Porpites.*

Community: The predominance of *Pentameroides* indicates a Pentamerid Community.

Interpretation: If the Pentamerid Community of the *Pentameroides* Beds directly succeeds the Stricklandid Community of the *Cyrtia* Beds, then a decrease in water depth surely took place.

Reference: Although a complete section bridging the *Cyrtia* Beds and the *Pentameroides* Beds has not yet been found, the latter are predicted to succeed the former. At Buck Creek in Delaware County (NE¼ NW¼ Sec. 20, T87N, R4W), a quarry exposes a 16.5 m section, the upper two-thirds of which become increasingly fossiliferous. A similar section amounting to 10 m can be found in the Hanken Quarry 2 km east of Iowa Highway 38, 5 km southeast of Monticello in Jones County (NW¼ NE¼ Sec. 6, T85N, R2W).

Goniophyllum "Beds"

The square coral *Goniophyllum pyramidale* is generally dated Wenlock in age, although an occurrence in Ireland cited by M'Coy (1846, p. 60) may be late Llandovery according to Ziegler, Rickards, and McKerrow (1974, pp. 64-65). In Iowa, *Goniophyllum* is associated with an extensive coral fauna, as reported by Calvin (1896, pp. 79-81). Presently no Iowa locality is known where rock strata may be examined, but in Jones County the silicified corals are recoverable from highly eroded deposits (geest) overlying the *Pentameroides* Beds. The abundance indicates a Coral Community. Environmentally, this reflects a resumption of shallow water conditions.

Callipentamerus "Beds"

From occurrences in subsurface strata of Nebraska, Carlson and Boucot (1967) date *Callipentamerus corrugatus* as very late Llandovery to early Wenlock in age. The distinctive pentamerid brachiopod was first reported by Weller and Davidson (1896) from highly eroded deposits in Jones County, and later redescribed by Boucot (1965). Calvin (1896, p. 73) mentions a locality in that county where a pentamerid variety was found in slumped strata above silicified corals and true *Pentameroides* Beds but the site has not been relocated. On the strength of the record, however, it is postulated that a *Callipentamerus* horizon exists above *Goniophyllum* and *Pentameroides* Beds. If so, the representation of a Pentamerid Community preceded by a Coral Community once again indicates a beginning rise in sea level.

SUMMARY AND CONCLUSION

Early to middle Llandovery deposition of the Edgewood and Kankakee Formations records a changeover from a *Lingula* Community to varying Coral Communities. Recurrent patterns of Coral, Pentamerid, and Stricklandid Communities indicate at least two repetitions of deepening to shallowing seas during the late Llandovery deposition of the Hopkinton Dolomite. In a sequence of deepening waters, a Coral Community is usually followed by a Pentamerid Community succeeded by a Stricklandid Community. The situation is always reversed under conditions of shallowing waters. An orderly sequence of communities, symmetric with respect to reversals in changing water depth, suggests that the regional geologic record in eastern Iowa is reasonably complete. Small breaks in the record, however, are not precluded. These are indicated by such features as planed *Pentamerus* shells with beak regions still in growth position, and the presence of stylolitic seams, or dissolution phenomena. Due to the gradation of community composition, stricklandid brachiopods of the Hopkinton Dolomite are common elements in some communities and minor ones in others. Phyletic development of this brachiopod provides a basis for framing successive depositional events in the perspective of time.

The platform communities now recognized in eastern Iowa may provide the opportunity to relate carbonate lithologies to communities previously associated mostly with continental margin, clastic sediments. Micritic dolomite characteristically occurs with the shallow Pentamerid Community of the *Cyclocrinites* Beds. A similar dense dolomite sometimes appears in various coral beds. Dolomites are more bio-clastic in composition, and generally occur with faunas of deeper water communities, such as the Stricklandid Community of the *Cyrtia* Beds. Difference in the lithologies stemming from shallow water deposition as opposed to deeper water deposition may be related, in part, to the depth range and other conditions under which certain algae best thrive.

Fluctuations in sea level recorded in the Lower Silurian of Iowa varied between depths compatible to Coral and Stricklandid Communities. The platform Coral Community is probably analogous to the continental margin *Eocoelia* Community. Substitution of one for the other may reflect the general preference of corals for carbonate environments remote from sources of clastic sediments. Lauritzen and Worsley (1974) estimate an upper depth limit for the Stricklandid Community, based on the association of *Girvanella* in Llandovery age rocks of Norway. *Girvanella* is thought to be a genus of blue-green algae belonging to the family Oscillatoriaceae. Modern forms of this family inhabit clear waters shallower than 60 m. If the Silurian platform and continental margin communities were restricted to similar depth ranges, then the sea level fluctuations on the North American craton most likely varied between a few and 60 m.

Glaciation, and in turn deglaciation, are two of the most powerful agencies capable of inducing global, or eustatic, fluctuations in sea level. Physical evidence indicates that during the last Pleistocene glaciation, sea level stood 130 m below the present level (Milliman and Emery, 1968). Traces of a late Ordovician glaciation are widespread across North Africa, and are suspected in South America (Berry and Boucot, 1973, 1972). A significant drop in sea level due to glaciation may account for local development of topographic relief in the Maquoketa Shale, and subsequent deglaciation may account for the resumption of marine conditions in the region. On a broader scale, Sheehan (1973) suggests that the same events might explain the disparity between late Ordovician and early Silurian brachiopod faunas in North America. Bennacef *et al.* (1971, p. 2241) report graptolitic shales of the Imirhou Formation (zone 18 or 19 of latest early Llandovery age) in the Algerian Sahara immediately above glacial outwash deposits of a type not prone to preservation if subjected to prolonged exposure. The implication is that deglaciation continued well into the beginning of the Silurian Period. At present, it is uncertain whether additional episodes of deglaciation played any role in causing sea level fluctuations of late Llandovery age. If other than regional factors were involved, it is expected that trends similar to those indicated by community patterns in the Hopkinton Dolomite should be detectable elsewhere in formations of the same age. Comparable strata in New York State (Ziegler *et al.*, 1971) and the Welsh Borderland (Ziegler, Cocks, and McKerrow, 1968) provide community and/or lithologic evidence for fluctuating sea levels. However, the Ross Brook Formation in Nova Scotia, also deposited throughout late Llandovery time, yields faunas belonging to only a single community, the *Eocoelia* Community (Boucot *et al.*, 1974, p. 43).

In conclusion, it is clear that the interpretation of ancient environments through time calls for a thorough, almost bed by bed, assimilation of paleontologic and lithologic data. The prerequisite is not an impossible one to satisfy in the mid-continent region of North America, where geological relationships are relatively uncomplicated. This paper reports only preliminary results from the study of Lower Silurian strata in eastern Iowa. A more comprehensive investigation is in progress with the expectation of clarifying the relationship of platform communities with carbonate lithologies, and establishing the correlation of environmental events between regions of Silurian epeiric and continental margin seas.

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