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PALEOECOLOGICAL INTERPRETATION OF THE ROGERS CITY LIMESTONE (MIDDLE DEVONIAN, NORTHEASTERN MICHIGAN)

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INTRODUCTION

THE ROGERS CITY LIMESTONE was named by Ehlers & Radabaugh (1938) when they recognized that the upper part of what had been known as the Dundee Limestone of Presque Isle County, Michigan, had a lithology and fauna distinct from that of the lower part of the "Dundee Limestone" (the "true" Dundee). It was recognized that the Rogers City fauna was similar to that found in the Winnipegosis Formation of Manitoba, Canada, and differed strikingly from the faunas in the underlying Dundee Limestone and the overlying formations of the Traverse Group.

The Rogers City Limestone outcrops in the northeastern part of the Michigan Basin. Because of extensive glacial cover the number of exposures are relatively few, but because of the chemical purity of the limestone two large quarries have been opened in the formation and, as a result, the formation is well exposed and understood in these two localities.

The total outcrop belt extends roughly 30 miles from Middle Island near Rockport Quarry to a point about two miles west of Rogers City where it disappears beneath the glacial drift. The two major outcrops of the Rogers City Limestone are in the Calcite Quarry of Michigan Limestone Operations of the U.S. Steel Corporation at Calcite, SSE of Rogers City ("the world's largest limestone quarry") and the Quarry of Presque Isle Corporation (formerly Lake-of-the-Woods Quarry) in eastern Presque Isle County, Michigan. In addition there are smaller surface outcrops on Middle Island, the beach north of Rockport Quarry, a good series of beach exposures on the north and east sides of False Presque Isle, poorer exposures on Presque Isle south of the lighthouse, the Adams Point Quarry, and two small road cuts west of Rogers City.

As a result our entire knowledge of the surficial Rogers City Limestone is based on about eight localities. Fortunately, two of these localities are indeed extensive, with the quarry near Rogers City providing almost six miles of continuous exposure in the walls of the quarry.

My interest in the Rogers City was initially stimulated by G. M. Ehlers and R. V. Kesling of The University of Michigan Museum of Paleontology. I had the very good fortune to accompany both of these gentlemen into the field in the northern Michigan area during the late 1950's, and for the last six years I have been working on various aspects of the magnificent gastropod fauna found in these beds.

The Rogers City Limestone was originally described (Ehlers & Radabaugh, 1938) as consisting of four units which were faunally and lithologically distinctive. More recently it was redescribed (Ehlers & Kesling, 1970) as having six distinctive units. As this latest description is more complete and consistent with the paleoecological interpretations I give below, I shall add my own observations to it.

LITHOLOGY AND GENERAL PALEONTOLOGY OF THE ROGERS CITY LIMESTONE

The paleontology of the Rogers City Limestone has not been given the attention it deserves. It had never been treated in its entirety until the publication by Ehlers & Kesling (1970). The magnificent plates that accompany their article (pls. 9–12) give an idea of the richness and diversity of the fauna of the Rogers City Limestone. Beyond this paper the only group that has received any concerted attention is the Bivalvia, which has been discussed by LaRocque (1949a, 1949b). More recently Kesling (1971) published on a most unusual starfish from the lower units of the formation.

The two basal stratigraphic units of the Rogers City Limestone are termed the *Emanuella* zone (Ehlers & Kesling, 1970). The lowest unit (unit 1) is an extremely fine grained dolomitic limestone about six feet thick. The bedding is thin, and upon weathering the rock breaks up into slabs that are two to three inches thick. The rock is essentially a buff-colored stone that is mottled with dark brownish-gray splotches. An examination of thin sections and peels shows that this mottling is caused only by a variation in color and there is no evidence of textural change over the color boundaries. In most of the rock of unit one there is no evidence of depositional structures such as graded bedding, banding, flute casting, orientation of grains, tracks, and trails, nor any evidence of burrowing. Only at one spot, on the southwest side of the Calcite Quarry of the Michigan Limestone Operations of the U.S. Steel Corporation, SSE of Rogers City, Michigan, have I found a bed preserving rather thick mud cracks, to break this monotony.

The one obvious variant in the unit is created by the presence of discontinuous horizontal bands of fossils; these shell hashes represent the only occurrence of fossils in unit one. The bands tend to be very thin, usually only one shell-width in thickness but occasionally a band of shells may be up to an inch thick. The bands are extremely well sorted as to size and shape of hard parts; consequently some bands may be made up almost exclusively of one species of organism. The frequent presence of the brachiopod *Emanuella* aff. *E. meristoides* (Meek) in these bands prompted Ehlers & Kesling (1970) to propose the name *Emanuella* zone.

These bands of shells contain a wide diversity of fossils, including the brachiopods *Carinatina dysmorphostrota* (Crickmay) and a productid in addition to *Emanuella*. The pelecypods include four described by LaRocque (1949b): *Actinopterella calliotis*, *A. peninsularis*, *Leptodesma furcistriata*, and *Limoptera* (*Myalinodonta?*) *migrans*. The smaller gastropods are particularly well represented by one loxonematid, two murchisonids, three bellerophontids (all undescribed), and *Straparollus* (*Straparollus*) *cottrelli* Linsley & Yochelson. Other gastropods which are characteristically large are occasionally represented, usually by immature specimens. "*Omphalocirrus winnepegosis*" Whiteaves has been found as well as opercula of this genus.

Both species of *Mastigospira*, *M. ingens* LaRocque and *M. intermedia* LaRocque (1949a), also occur in unit one. These shells are particularly interesting because their pronounced elongation exhibits very striking lineation. *Mastigospira* shells are frequently found associated with other conical shells, such as very large tentaculitids and enigmatic tubes that have been assigned doubtfully to *Dentalium*. All three forms tend to be specimens of similar size, and all shells show alignment on some bedding surfaces. On these beds the axes of the shells tend to be parallel, but the apices of the shells do not necessarily point in the same direction, which suggests wave action rather than a unidirectional current.

Other fossils from unit one include the trilobite *Dechenella* (*D.*) *valentini* and crinoid columnals. Although the unit has been extensively collected, it still yields surprises; recently a rare starfish, *Michiganaster inexpectatus* Kesling, was found (Kesling, 1971).

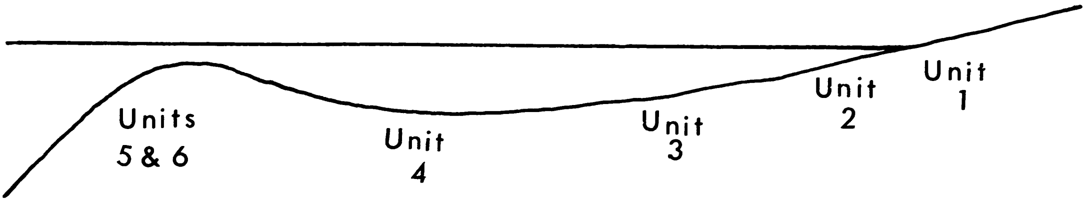
Unit two of the Rogers City Limestone is only two feet thick and is generally considered transitional between units one and three. It is still a dolomitic limestone, though with less magnesium than unit one. Like unit one, this unit is irregularly mottled by dark-gray splotches on the light, buff-colored rock. It is thicker bedded than unit one and fossils are less abundant. No bands of shells have been found in this unit.

Ehlers & Kesling (1970) characterize units three to six of the Rogers City Limestone as the *Omphalocirrus* zone. Within this larger zone they separate unit three as the *Atrypa* zonule and unit four as the *Gypidula* zonule.

Unit three, the *Atrypa* zonule, is brownish to buff-gray, even-bedded, porous limestone about five and one-half feet thick. The matrix of this unit is composed of silt-size particles of lime containing bioclastic debris composed largely of fragmented brachiopod shells and crinoidal debris. Occasionally small clumps of micrite can be seen in the bioclastics. The brachiopod *Atrypa arctica* Warren dominates the fauna of this rock, but a few specimens of *Gypidula* can be found. *Buechelia*, *Gyronema*, "*Omphalocirrus*," and other gastropods also occur sparsely.

Unit four, the *Gypidula* zonule, is a dark, fine-grained, thick-bedded limestone with a brownish-gray color. The fauna is dominated by the brachiopod *Gypidula*, which locally forms a coquina with the shells forming 30% to 40% of the bulk of the rock, but other brachiopods such as *Atrypa arctica* and *Subrensselandia* sp. are also present. Gastropods are moderately abundant with "*Omphalocirrus*," *Buechelia*, *Gyronema*, *Straparollus*, and a variety of others present. The coral *Hexagonaria borealis* Stumm occurs and some specimens are upright in the micrite in what might have been their growth position. Again the matrix of the rock, with that of the underlying unit, is micrite with bioclastics forming a sizeable constituent. This unit is six and one-half feet thick.

Unit five is the thickest in the Rogers City, measuring thirty-four feet. It is medium-bedded (6″ to 8″) and buff to buff-gray in color. The matrix is fine- to medium-grained micrite containing large quantities of bioclastics, which may constitute as much as one-third of the bulk of the rock. In the upper part of this unit, the clastic particles are well



TEXT-FIG. 1—Ecological interpretation of the various units of the Rogers City Limestone.

rounded but they are not oolites. None of the fossils or bioclastic material shows any preferential orientation.

Unit six is seventeen feet thick and generally resembles unit five. It is predominately buff-colored, thick-bedded (12″ to 16″) limestone. Stylolites are abundant in both units five and six. The matrix is generally finer grained than that of unit five, and bioclastic debris seems to be slightly less abundant although it increases towards the top of the unit.

The fauna of units five and six is similar. In both it is rich and diversified. Unlike the lower four units in which individual shells are common, the upper units are dominated by colonial forms with a large number and variety of corals, stromatoporoids, and trepostomatous bryozoans. Most of the larger colonial organisms appear to be in living position. In addition to the corals, bryozoans, and stromatoporoids, the fauna of these two units includes over twenty species of gastropods, fifteen cephalopod species (Russeau Flower, written communication, 1969), as well as a large number of pelecypods and brachiopods. Crinoid columnals are abundant but no calyces are known. I have found two specimens of the rare sponge *Sphaerospongia tesselata* Phillips, not previously reported from this locality.

The colonial organisms are distributed fairly randomly throughout the uppermost two units and are not built up into a mound. Many of the stromatoporoids encrust shells, particularly those of gastropods and brachiopods, the two most common shelled organisms in the unit. The relative abundance of the mollusks can be at least partially attributed to the number of external molds formed by this encrusting growth habit. In fact almost all the mollusks are preserved as molds or natural casts.

In contrast, the skeletons of the brachiopods, corals, stromatoporoids, bryozoans, and crinoids have not been replaced. This attests to the presumed aragonitic composition of the molluscan shell as opposed to the calcitic composition of the other tests. The stromatoporoids encrusted many of the mollusks so completely and so tightly that when the aragonite was dissolved, an extremely faithful external mold was left on the inside of encrusting stromatoporoids. Some of these stromatoporoid geodes also had sufficient strength to resist compaction so that the resultant molds have not been crushed and show essentially no deformation.

In the Calcite Quarry near Rogers City, the molds of gastropods from units three to six are quite clean with only occasional scalenohedra of yellowish calcite lining the molds. As one traces the Rogers City Limestone to the south, however, the molds contain progressively more secondary calcite filling. At the beach outcrop 0.6 miles north of the northern boundary of Rockport Quarry and on Middle Island, the molds have been so completely filled with secondary calcite that the preservation of mollusks in these places is in the form of natural casts rather than molds.

DEPOSITIONAL ENVIRONMENT AND PALEOECOLOGY OF THE ROGERS CITY LIMESTONE

The rare mud cracks found in unit one indicate that the unit was subaerially exposed at least some of the time. Additionally, the extremely fine grained nature of the rock suggests that it might be a dolomite deposited on a mud flat, like the beds found on Andros Island in the Bahamas (Shinn, Ginsburg, & Lloyd, 1965) or on Sugarloaf Key in the Florida Keys (Shinn, 1964). The well-sorted and banded deposits would also be consistent with this interpretation, for they could be the result of severe storm action washing shells up onto the mud flats.

The well-sorted nature of the shell hashes suggests that wave energy was primarily responsible for introducing the shells on the mud flats. This is supported by the fact that whereas any given layer shows good sorting, the deposits are restricted in lateral extent and there is considerable variation in shell size from layer to layer. The lineation of elongated shells is quite variable. On some surfaces no alignment whatever can be discerned, but on others alignment is strongly marked directionally for the axes but not for the apices. This evidence would be consistent with shell deposits dumped suddenly by large waves washing shell debris over a beach onto a mud flat where dolomites could form. Most frequently modern deposits exhibit size sorting, but show orientation only where localized currents are set up by incoming or outgoing water currents.

In such an environment algal mats might be expected, but careful examination of the outcrops of unit one has shown no indication of stromatolites anywhere. Nevertheless I believe that this unit was deposited at or near the strand line. Either the unit was just above the strand line as a supratidal dolomite with debris washed-in rarely, or just below the strand in a very shallow, restricted environment having poor circulation and extreme ranges of temperature and salinity. In either interpretation I believe that all the fauna is introduced. If it was indeed a shallow-water, restricted environment, it may be theoretically possible that *Emanuella* was endemic, and possibly one or two other species, such as the tentaculitids, but I don't believe it. The other fossils found in this unit are represented in the other units where they probably lived, and were winnowed out of these units by storm action and cast into the area where unit one was being deposited.

Unit two most closely resembles unit one and differs from it mainly by being less dolomitic. Most probably it represents the top two feet of unit one agitated by waves. I cannot account for the mottling found in the two units, but rather suspect it is a diagenetic product and of little significance in interpreting the environment of deposition. Possibly *Emanuella* was endemic to unit two, but the evidence supporting this conclusion is not very impressive.

Unit three contains an impoverished fauna such as one might expect in a restricted environment. The sediment is predominately a very fine lime mud which was probably washed into a very shallow area. The only clastic particles are either bioclastic in origin or clumps of mud; these clumps are best interpreted as consolidated pieces picked up by a storm and redeposited. This phenomenon again suggests a very shallow sea where the sediments could be easily disturbed by severe storms. In general, the fossils and lithology indicate a restricted area not unlike Florida Bay or the Bahama Banks, where faunal diversity is restricted by extreme fluctuations in temperature and by salinity changes.

Occasionally and locally, conditions reflect somewhat more stable marine conditions which allowed some marine organisms that were tolerant to extremes to penetrate the area. Populations may be high in numbers of individuals but low in numbers of species, a general condition in stress areas (Bretsky, 1969). The presence of *Atrypa arctica* with its grotesque frill suggests that this organism was well adapted to perch on soft muds (Copper, 1967), even in an environment occasionally subjected to bursts of high energy. The presence of *Gypidula* in this unit also is indicative of shallow water, as *Gypidula coeymansensis* plays a similar role in a presumably similar environment in the Helderberg Group of New York State (Rickard, 1962; LaPorte, 1967; and Anderson, 1971).

Unit four, though still rather shallow, would seem to represent a somewhat deeper water faunal assemblage. Perhaps more important is that it was an area of mixing marine waters of normal salinity with the more variable waters responsible for deposition of unit three. The fauna of unit four is more varied than that of any of the preceding units. The presence of a few corals particularly suggests more tolerable conditions of salinity and/or temperature, though not those conditions which would favor widespread coral-stromatoporoid growth. In all, I interpret this unit as deposited in an environment between the shelf-edge environment of units five and six and the shallow, restricted environments of units one through three. It is intermediate in terms of faunal abundance as well as presumed ecological conditions. Because the fauna is somewhat restricted, the bathymetric situation could have been a slightly deeper basin than was the case of the adjacent units. The reduced wave energy would explain the abrupt change in fauna and lithology from unit four to unit five.

Units five and six, with their lush stands of corals, stromatoporoids, and stony bryozoans and their very diverse molluscan and brachiopod assemblages, suggest normal marine conditions in terms of temperature and salinity. The presence of well-rounded clastic grains suggests agitated water, well above wave base. I suggest that perhaps the setting of these units was on a shelf edge where water from a more open epeiric sea was encroaching onto a flat shelf which formed the setting for the units of the Rogers City Limestone (text-fig. 1).

The total thickness of the formation is exposed at only two places: the Calcite Quarry just south of Rogers City (T 35 N, R 5 E, secs. 23, 25, 26, 35, and 36, Presque Isle Co., Mich.) and the Quarry of the Presque Isle Corporation (formerly Lake-of-the-Woods Quarry, T 35 N, R 8 E, sec. 2). The six other localities at which the Rogers City Limestone is exposed (Ehlers & Kesling, 1970, p. 26) are surface exposures and show only part of the formation. Even with limited exposures there seems to be little variation in lithology; subsurface data indicate at the most minor changes from hole to hole.

Throughout its outcrop belt of thirty miles, the Rogers City Limestone maintains the same sequence of its units with relatively minor thickness changes from 70′ to 100′. Units 1–4 are relatively uniform with little apparent lateral variation, with most of the changes in thickness accomplished by variations of units 5 and 6. This could indicate that the present outcrop belt of the Rogers City Limestone paralleled the strand line during the period of deposition. In a broader context, the present form of the Michigan Basin strongly suggests that during the Devonian Period the land mass was east of the outcrop area and that the sea transgressed from west to east.

SUMMARY AND CONCLUSIONS

The rocks of the Rogers City Limestone are interpreted as having been deposited in shallow water overlying a carbonate shelf, the base of which was formed by the underlying Dundee Limestone. This situation is partially analogous to the modern Bahama Banks. The Rogers City sea is believed to have transgressed from west to east. The present outcrop of the Rogers City Limestone is presumed to be roughly parallel to the shore line.

The six vertical stratigraphic subdivisions of the Rogers City Limestone are interpreted to represent a variety of environments, ranging from supratidal dolomites at the base, to well-agitated and aerated open-water biostromal deposits at the top. All the units are presumably shallow-water limestones, though the primary factors in determining the nature of the sediments were considerable ranges of temperature, salinity, and turbulence in a generally transgressive sea.

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