GENERAL SCIENCE NOTES

FOSSIL BINDING IN MODERN AND ANCIENT REEFS

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WHAT THIS ARTICLE IS ABOUT

Fossil reefs are reported from many parts of the world, especially for the Paleozoic era. While binding of reef components by carbonate-secreting organisms is an undisputed fact for modern reefs, such binding for Paleozoic reefs is not generally observed. Other major differences include the size, taxonomy and abundance of reef-building organisms and the composition and coarseness of matrix material. Such differences make use of the term "reef" for the Paleozoic structures highly controversial.

An extended period of time is necessary for organisms to build a modern reef. The same would seem to apply to ancient reefs described in the geologic record of the past. Are these ancient reefs true reefs that took a long time to develop? We shall consider some comparisons between modern and ancient reefs.

A. GREAT LAKES FOSSIL REEFS

The geological literature states that fossil reefs are found in many parts of the world. Many reefs are reported from the Paleozoic era which includes the Silurian and Devonian periods. The fossil reefs of the Great Lakes region in Silurian and Devonian rocks have been studied fairly intensively for about 60 years. These Great Lakes reefs are composed of a central mound or core of massive dolostone (Silurian) or limestone (Devonian), surrounded by flank beds which dip away from the central core. The cores may be a few feet to many hundreds of feet across. Parts of such reef complexes can be observed in limestone quarries, roadcuts, and outcrops.

When the average person thinks of a reef, he envisions a beautiful, colorful, underwater scene with rock-like coral and algal growth, fish, and other marine plants and animals. He might then expect that corals and other calcareous rock-forming organisms would be essential and important parts of the fossil reefs which now are found elevated on dry land, and assumed to have grown in the ocean. This expectation is in fact the case for "modern" fossil reefs now found in such places as the Florida Keys, Jamaica, and Barbados. But what of the fossil reefs of the Great Lakes region? Are they composed largely of a framework of corals and other calcareous binding fossils?

FIGURE 1. Very fossiliferous zone in a bioherm in the Formosa reef limestone near Formosa, Ontario. Laminar stromatoporoids, rugosan corals and crinoids are abundant. Such fossil abundance is atypical in Silurian and Devonian reefs.

To the contrary, a casual inspection of the outcrops of fossil reefs of Silurian and Devonian age indicates that they are generally devoid of larger, framework-type fossils. Only small portions of some of these outcrops appear to be very fossiliferous or moderately so. Figure 1 is a photograph of an atypical, very fossiliferous zone in a Devonian reef near Formosa, Ontario, Canada. From an inspection of outcrops of many reef, reef flank and interreef localities in the Great Lakes region, the outcrop areas with an obviously significant content of binding fossils are estimated to be considerably less than 10% of the total area of the outcrops. Most rock surfaces (over 90%) have no obvious larger fossils or only scattered fossils. Figure 2 is a photograph of a "baby reef" in a "reef" complex at Richvalley, Indiana, which is nearly devoid of framebuilding fossils. One could argue that most of the original fossil material has undergone dissolution, replacement by dolomite, or other obscuring processes. While some dissolution and replacement have undoubtedly occurred, the fossils presently seen in the fossil reefs are quite well-preserved in many cases and can be identified often to species level. These fossils are not generally observed to be partially dissolved or replaced to a significant degree, also suggesting that fossil dissolution and replacement are not pervasive.

Laminar and globular stromatoporoids, stromatolites, tabulate corals, etc., are probably useful as fossil framework and binding agents in those areas with some fossil abundance. However, even where fossils occur in some abundance, the actual area of the outcrop covered by framework fossil material is generally less than 10% except for a few isolated cases. For all the reef core and flank areas studied in the Silurian and Devonian, the actual rock surface area covered by larger fossils is roughly estimated to be in the 1% range. This does not build a convincing case for the fossil reef interpretation of these limestones and the presence

FIGURE 2. A "baby reef" occupies the central portion of this photograph from a long railroad cut in a reef complex near Richvalley, Indiana. The baby reef and surrounding rock are nearly devoid of larger fossils such as corals. This is typical of most reef outcrops in Silurian and Devonian rocks.

of fossil framework as an essential binding agent for these so-called reefs.

Finally, a look at the matrix (the finer-grained portion of the rock surrounding the fossils) of the Silurian and Devonian reef rocks indicates that in most places, the matrix is primarily lime mud and/or cement, rather than sand-sized grains. (I am not making a distinction here between dolomitic mud and lime mud.) At most reef sites the mud-sized fraction of the matrix greatly dominates over the sand-sized fraction. Because mud grains are silt or clay-sized, that is, fine-grained, their origin (fossil or other) is not usually determinable.

B. FLORIDA — THE KEY LARGO LIMESTONE — A MODERN REEF

The above-noted paucity of fossils in the Silurian and Devonian reefs is in contrast to the Pleistocene Key Largo Limestone of the Florida Keys, which I found to be abundantly fossiliferous in framework-binding corals such as *Montastrea annularis* and *Diploria* at 4 sites. Figure 3 is a photograph of the coral-covered wall in the Windley Key quarry. This is typical of the rock surfaces at all sites. There are no significant outcrop areas at these sites where corals are not present. This is in sharp contrast to the situation in the Silurian and Devonian reefs.

The coral content of the Key Largo Limestone on a vertical outcrop wall in a quarry on Windley Key was studied in detail by Pasley (1972). Pasley measured the percentage of rock surface covered by various species of coral on a section of quarry wall 6 feet in height by 41 feet in width, an area of 246 square feet. He also made a map of the wall outlining the coral on the wall by species. Coral covered 30.7% of the study area, almost one-third. Of the coral-covered area, 50% was covered by *Montastrea annularis*, which often has a large multi-lobed growth form a meter or more in diameter. *Diploria* (four species) made up 23% of the coral area. *Diploria* also often has large heads, but not quite as large as the largest *Montastrea* heads. *Porites* (two species) covered 20% of the coral area. *Porites* are smaller corals but are also good rock-binding corals. Other species of corals made up the remaining 7% of the coral-covered area.

Earlier, Stanley (1966) reported on a similar study of the same Key Largo Limestone, but did not give as much detail on the coral. He did, however, give fossil information on the matrix portion of the rock. Stanley

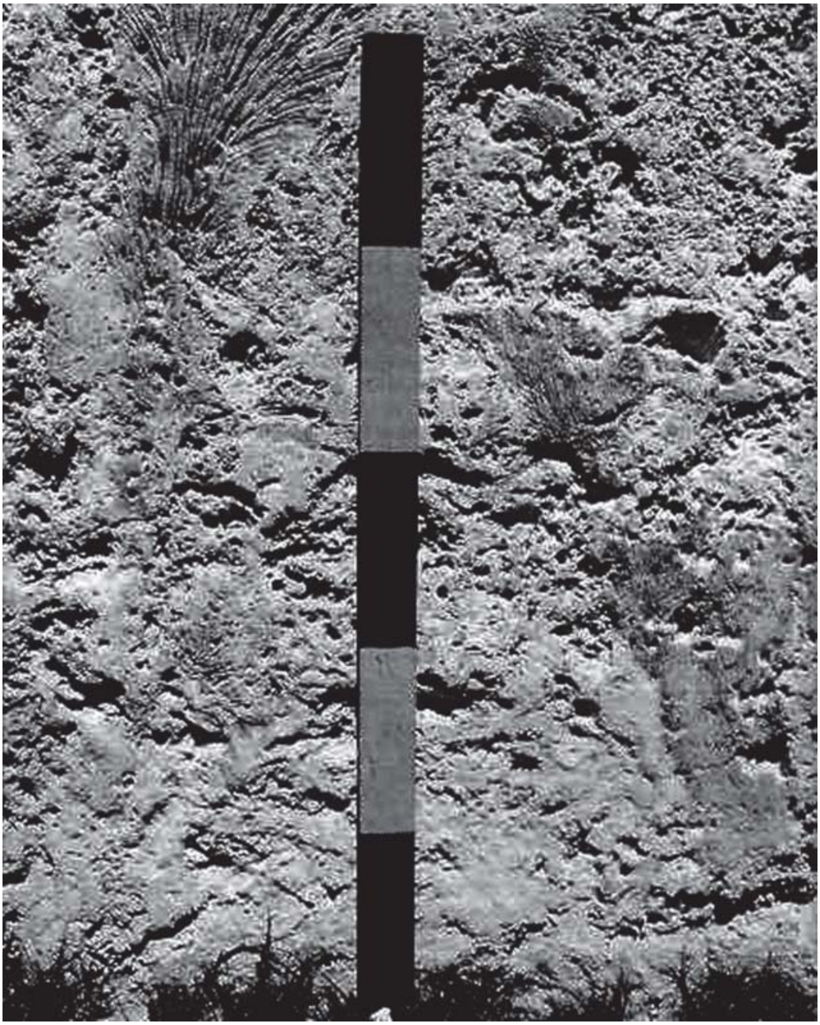

FIGURE 3. Typical coral-covered wall in the Key Largo Limestone at Windley Key Quarry, Florida. Two large corals are a *Diplora labyrinthiformis* at the upper left and a *Siderastrea siderea* at the lower right. Scale rod is 5 feet (1.52 meters).

found that 31 % of the rock was composed of coral framework, with *Montastrea annularis* the principal frame builder, forming 17% of the rock. This was followed by *Diploria* at 10% and *Porites astreoides* at 4%. The sand-sized portion (calcarenite) of the interstitial matrix made up 41% of the rock, with the following fossil composition (percentages relative to all the rock): *Halimeda* 17%, mollusks 7%, coral fragments 4%, red algae 3%, forams 2%, and minor and unidentified 8%. Note that the coarser matrix (calcarenite) is essentially a fine fossil “hash.” Calcilutite (lime mud) made up 28% of the rock. The mud itself may in part be composed of silt and clay-sized fossil debris. Thus the Key Largo Limestone is composed of a minimum of 72% fossil material.

In summary, it is clear that the binding-fossil content of the Pleistocene Key Largo Limestone is much greater and much more significant for binding than that of the Silurian and Devonian reefs of the Great Lakes region. The fossil content and the grain-size distribution of the matrix of these rocks are also in sharp contrast. Similar conclusions are found on p 447 in the well-known text on sedimentary rocks by Blatt, Middleton and Murray (1980), where they state:

> *Closer inspection of many of these ancient carbonate ‘reefs’ reveals that they are composed largely of carbonate mud with the larger skeletal particles ‘floating’ within the mud matrix. Conclusive evidence for a rigid organic framework does not exist in most of the ancient carbonate mounds. In this sense, they are remarkably different from modern coral-algal reefs.*

Similar conclusions may be reached concerning the world-famous Permian Capitan reef complex of southeastern New Mexico and western Texas in the Guadalupe Mountains. Hayes (1964) states:

> *The massive member of the Capitan Limestone is interpreted to be a reef deposit made up of the remains of marine organisms; however, upon cursory examination it seem to be only sparsely fossiliferous at most places.*

Hayes (1964) goes on to state: “Small profusely fossiliferous patches of rock can be found, however.” This general lack of framebuilding fossils and the presence of small very fossiliferous patches is exactly the situation noted above for the Great Lakes “reefs.” Dunham (1970) states that binding at the Capitan reef is wholly or largely inorganic (i.e., lime cement), and concludes that the Capitan reef is not an ecologic reef. This means that it is not a reef in the sense that modern reefs are.

C. GREAT LAKES REEFS — CARBONATE MUD MOUNDS?

We have noted the contrast between the framebuilders and matrices of the Great Lakes Paleozoic reefs and the Florida Pleistocene reefs.

Recently there has been less of a tendency to call the Paleozoic reefs of the Great Lakes region reefs in the modern sense. That is, these structures are less likely to be characterized as wave-resistant, organic-framework reefs. Currently, there is a trend to identify these reefs as carbonate mud mounds, implying that binding fossil framework and the resulting wave-resistance are not characteristic, but that carbonate mud is the dominant feature (Textoris 1966). After visiting many of these Paleozoic mounds, I concur. Rather than originating in the shallow surf zone, Pratt (l982) thinks the Paleozoic mounds originated in moderately deep water, occasionally at depths of 100 meters or more. Pratt attributes the binding in these mounds to types of bluegreen algae (non-calcareous) and cement. Earlier, Coron and Textoris (1974) dissolved 75 rock samples from the classic Silurian reef at Wabash, Indiana, in acid. The residues in some cases contained filaments resembling various kinds of non-calcareous algae. In both the Pratt (1982) and Coron and Textoris (1974) papers, the emphasis was on non-calcareous algae, rather than the encrusting, framebuilding calcareous algae, associated with modern, shallow-water reefs.

While noting the lack of wave-resistant framebuilders in the Paleozoic reefs, a paper by Hodges and Roth (1986) shows that coral-bearing Paleozoic mounds, while relatively sparse in coral content, are not disordered piles of debris, especially in the central core region. Corals in the core are primarily upright in position, suggesting that either the cores are in their original position, with upright coral growth, or have been transported with no appreciable tilting.

In conclusion, it is clear that the Paleozoic reefs of the Great Lakes region are markedly different in many respects from the modern-appearing Pleistocene reefs of Florida. Still, relatively little is known about the origin and ecology of the Paleozoic reefs of the Great Lakes region and their fascinating, important, and often-controversial role in deciphering Earth’s history.

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