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Unusual Beach Deposits in Oolite Carbonate Environments Mississippian and Recent

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Thousands of small fossils were collected from unusual lenses within the *Cyathophyllum* Zone, Gilmore City Limestone (Mississippian) in a large quarry near Humboldt, Iowa. These rare lenses occur in an interval 1-2.5m thick that shows an extreme variability of facies. An intensive search of other Gilmore City outcrops revealed no similar lenses. The rest of the interval, outside the lenses, contained larger fossils and fossil fragments. The small fossils in the lenses are remarkably well preserved, the gastropods particularly so. Comparison of the Gilmore City Limestone with Recent oolitic deposits at Paradise Island in the Bahamas leads to the conclusion that these unusual lenses probably were a backshore deposit. The Bahamian deposits provide evidence for interpretation of these fossils as size-sorted rather than dwarfed. Early carbonate coating is hypothesized to explain the exceptional preservation of the Mississippian fossils.
INDEX DESCRIPTORS: Mississippian, Gilmore City Limestone, Recent Bahamian beach deposits, fossiliferous lenses, lithofacies.

During the past 12 years, we have collected exceptional fossils from Hodge's P and M Quarry, northeast of Humboldt, Iowa (Ctr. of Sec. 32 T92N, R28W, Humboldt Co.). The parent limestone lies within the *Cyathophyllum* Zone (Laudon 1933; = *Vesiculophyllum sedaliense* White, Carlson, 1964) of the Gilmore City Limestone (Mississippian). Harper (1977) suggested that the Gilmore City Limestone could be as young as earliest Osagean or as old as Kinderhookian.

Our original collecting in Hodge's Quarry was on a random basis. However, several years of systematic search revealed that the best specimens were confined to an interval with an extremely variable facies. Thorough search of this interval disclosed fossiliferous lenses with small, biologically diverse, and exceptionally well preserved specimens. These small fossils could have been interpreted as a dwarfed fauna. However, the small fossils were confined to these lenses, and the rest of the interval contained fragmentary and whole larger fossils. Eventually, these lenses were interpreted as a beach deposit although the mechanism for size-sorting and deposition in a manner that resulted in minimal abrasion remained unknown.

In February 1980, one of us (A.J.G.) studied the oolitic carbonate beaches of Paradise Island in the Bahamas. After observing the various environments and deposits on the island, it was concluded that the backshore deposits provide a plausible modern analog for the Humboldt lenses.

The Hodge's Quarry lenses have yielded more than 50,000 whole specimens, mainly of ostracodes and gastropods but including abundant brachiopods, pelecypods, bryozoans, and annelids. In addition they contain fragmentary crinoids, blastoids, echinoids, trilobites and chiton plates. This collection presently includes more than 80 species of gastropod, 13 of ostracode, 16 brachiopod and 20 pelecypod. Of these, 50 or more gastropod species are new. There are several new ostracodes, including 2 new genera, at least 5 new brachiopod species, and possibly several new pelecypods. The gastropods are remarkably well preserved for Paleozoic specimens (R. Linsley, 1979, oral comm.). Most specimens fall within a size range from 0.5 to 5mm with a few gastropods reaching a height of 12mm.

Initially, specimens in this interval were collected from small random lenses up to 8cm in diameter and several cm thick, apparently deposited in shallow ripples. Extremely fossiliferous lenses as large as 100cm in diameter and 20cm thick were found later. Part of one such lens, 7x22x30cm, yielded more than 3000 specimens; more than 100 species are represented. Most of the fossils obtained in this interval were collected from less than 12 large lenses.

Occurrence and content of these lenses has generated substantial interest. Dr. John Harper, while a student at Pittsburgh University, described the gastropods of this collection as part of his doctoral dissertation. In addition, Dr. I. G. Sohn, U. S. Geological Survey, is currently studying the ostracodes, and Dr. John Carter, Carnegie Institute of Pittsburgh, is investigating the brachiopods. Shirley Sixt, University of Iowa, is studying the sedimentology, and Drs. Robert Linsley and Bruce Selleck, Colgate University the paleoecology.

HUMBOLDT OCCURRENCE

Hodge's Quarry, the source of the fossiliferous lenses, is operated by the Weaver Construction Company, Iowa Falls, Iowa. In the past, quarrying occurred in 2 adjacent quarries, with the west quarry located in the SE 1/4, NW 1/4 and the east one in the SW 1/4 NE 1/4 of Sec. 32, Grove Twp., Humboldt County. Recent operations

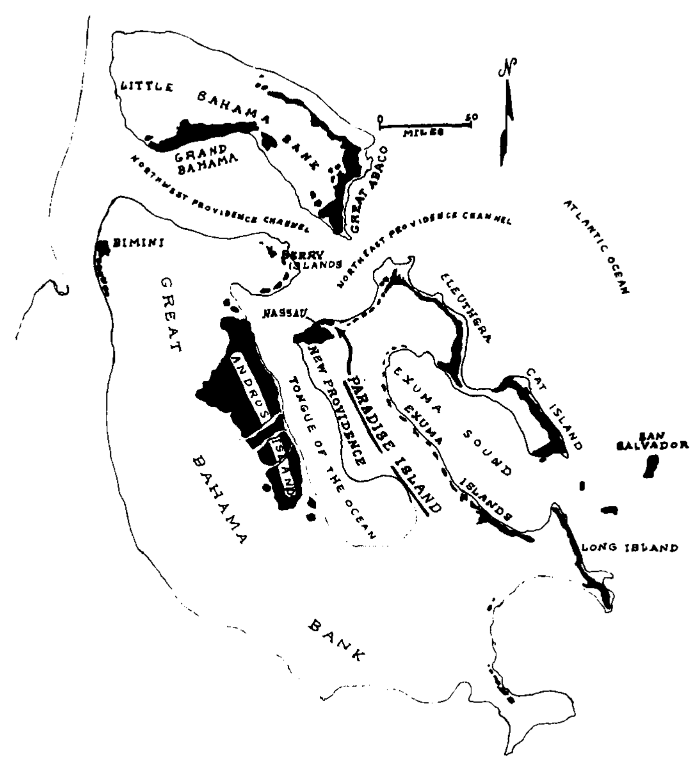

Figure 1. Location map, Paradise Island, Bahamas.

have joined the 2 quarries. The large lenses were located in the southsouthwest of the west quarry and the south portion of the east quarry. The entire original east quarry and a large portion of the west have now been mined and crushed. It appears that the large lenses were restricted to 2 irregular bands, 1 in each of the original quarries. However, sporadic operation and the long duration of quarry development made it difficult to interpret the geometry positively.

Thickness of the limestone section is 85' on the east face. D. Crowe and J. Schneyer, students at Colgate University in 1980, performed a lithofacies analysis of the upper 48' of the section on the south face of the east quarry; study involved thin-sectioning and microscopic study of slabs. Based on this study, 4 separate depositional environments were postulated: going upsection, a high energy to supratidal flat, hypersaline lagoon, ooid bank and normal intertidal flat. The present paper is concerned with a fossiliferous interval that includes a small portion from the top of their hypersaline lagoon environment and the basal portion of the ooid bank.

Despite an intensive search of the *Cyathophyllum* Zone (Laudon, 1933) in Iowa, no similar large lenses were discovered. However, some small fossiliferous lenses somewhat like those at Hodge's do occur at a small outcrop along the Des Moines River in Humboldt, Iowa, SE 1/4, Sec. 1 T91N, R29W.

The large fossiliferous lenses at Hodge's Quarry were found in an interval 1m to 2.5m thick whose top is approximately 9m below the top of the east face of the quarry. During December, 1979, a section of the west quarry was blasted exposing one of these large lenses *in situ;* it was almost 3m in length and varied in thickness from 5 cm to 20 cm. In May, 1980 this face was blasted outward, exposing most of the lens. Its width was found to vary from 20-60 cm and the rock was seen to be extremely bioclastic and fossiliferous.

The rocks of this fossiliferous interval show rapid lateral and vertical facies changes and include: well-cemented oolitic calcarenite, richly bioclastic and oolitic calcarenite, micritic oolite and friable oolite. The micrite content within all of these rocks is particularly variable but the most striking feature of this interval is the rapidity of change, within a few centimeters from an almost entirely bioclastic, micritic limestone to a fine oolite. Oolitic calcarenite is the predominant rock in the interval under description. It is strongly cemented, with angular and worn bioclastic fragments, and contains few complete well preserved fossils. Less common in this interval is a calcarenitic oolitic limestone whose enclosed bioclasts show less wear than those of the predominant rock type; worn fossils are scattered throughout this rock. Also contained in this rock are small lenses up to 8 cm in diameter and several centimeters thick in which there are some well preserved specimens. The richly bioclastic, calcarenitic, well-cemented limestone is an even less common rock and occurs in masses from 0.5 to 1 m in diameter and thickness. Within these masses are some complete and moderately well-preserved fossils, but they are larger and more worn than those of the large lenses. The large lenses were found in the same general area as the bioclastic masses. Friable oolitic limestone, the last lithic type, is rare. It can be 1 m to 2 m thick and up to 10 m in areal extent. Usually, worn ostracodes are the only fossils in this rock.

The small lenses display marked variation in the type of matrix as well as in the amount of wear on the fossils. By contrast, the large lenses usually have a matrix of medium-sized bioclasts with intermixed ooids and micrite forming loosely cemented limestone. This rock is readily fragmented to free numerous well-preserved fossils. An extraordinary feature of the large lenses is the extreme concentration of fossils per volume of rock. The vertical changes in the matrix adjacent to these large lenses are more abrupt than lateral variations, but lenses also tend to feather out into the adjacent rock. In most of the large lenses there is an abrupt change to a fine oolitic limestone on one edge of the lens. Above the fossiliferous layer of the lenses, the facies grade upward through medium-sized bioclasts containing few complete fossils to an oolitic calcarenite.

Fossils of the large lenses represent a more diverse fauna and are always smaller, on the average, than those of the small random lenses. The majority of the specimans in the large lenses are well-preserved; the opposite is true of the small lenses. Also, there is a lower concentration of specimens in the small lenses. In the large lenses most of the fossils have a thin carbonate coating, so loosely cemented that ordinary water often suffices for its removal. Such a coating is less common on the fossils of the small lenses or on those in the bioclastic, calcarenitic masses. Dr. Selleck (October 1980, oral comm.) noted this coating and hypothesized that it had an effect on the preservation of the fossils, especially of the gastropods. Some gastropods without ornament can be found in other rocks of this interval, but the well-preserved, ornamented specimens are almost entirely restricted to the large lenses. Occasionally, good specimens of brachiopods, pelecypods, ostracodes and bryozoans can be collected outside the lenses. However, only gastropods with this coating appear to have the delicate ornamentation preserved.

Only a small portion of the thousands of tons of rock in this interval contained the fossiliferous lenses, thus indicating an unusual environment of deposition. Harper (1977) compared the lenses with beach deposits along the east coast of Florida, and Sohn (1979) postulated origin in a back reef lagoon.

RECENT ANALOG

A plausible modern analog for the Hodge's Quarry lenses is provided by the sandy oolitic beaches of Paradise Island, Bahamas, studied during February 1980. Paradise Island, approximately 1.2 km by 4km is oriented roughly east west, with its north shore exposed to the Northeast Providence Channel (Figure 1). A bay on the northeast is protected by a small island reef. The beach sand on the north of the island is formed almost entirely of small angular to rounded shell fragments; complete shells are buried only infrequently. The sand of the northeast bay is a fine oolite devoid of identifiable shell. These sediments are similar to the bulk of the unfossiliferous interval in the Hodge's Quarry section.

The south coast is rocky Pleistocene shore indented by two small embayments with sandy beaches. It roughly parallels New Brunswick Island, from which it is separated by a shallow narrow arm of the sea with an average depth of 3 m. The beach on the eastern embayment is known locally as Love Beach. On its east end is a small backshore protected by a Pleistocene prominence that rises to 1.2 to 1.5 m above normal tides. At the time of observation, this backshore lodged a shell deposit with an areal size of 3 m in length, tapering from 45 cm width on the south to 15 cm on the north; this deposit was obviously accumulated at a time of high water. The 1.2 to 2.4 m interval between the rocky shore and the shell deposit was covered with coarse bioclasts similar to the matrix surrounding the lenses at Humboldt. To the land side, sharply delineated from the shell deposit, was a fine oolitic sand with intermixed fine shell clasts. This deposit of relatively small size-sorted shells contained 110 species of molluscs, 2 species of ostracodes, and an undetermined number of foraminiferal species.

Two hundred meters west of Love Beach is Shell Beach, located on the other small embayment. This beach also had a small backshore with a shell deposit on the east end. These were the only such deposits on Paradise Island. The Shell Beach deposit contained larger shells with coarser clastics intermixed. The sand on the main beaches of both embayments is a medium-sized oolite containing some buried shells.

Knowledgeable Paradise Island residents maintain that these deposits were the result of coincidence of southwest winds with high tides. These uncommon conditions prevailed no more than 2 to 4 times annually. Midway through February, 1980 these conditions were sustained for 2 days. By the 2nd day, the deposit at Shell Beach was almost completely covered by shell hash. However, the deposit at Love Beach had little material added. It was observed that the protective shore at Shell Beach was lower, and also that the deposit at Love Beach was protected from the full force of the waves by a rocky point at the west end of the embayment. A slight change of wind direction with a higher tide would have deposited more material on the Love Beach backshore.

At Love Beach, the backshore was an average 30-60 cm below the greatest height of the old protective rocky shore. Only the smaller, lighter shells were rafted over the protective parapet; the water surged gently to the high water mark, depositing these shells but leaving the coarse bioclastics between the parapet and the shell deposit. Recession of the water was slow, leaving the shells and clastics scarcely disturbed. At Shell Beach the protective shore was lower and, consequently, larger shells were rafted to the backshore.

Not all such depositional episodes as observed in the Bahamas would result in shell accumulations that could eventually be preserved. However, the deposits on Paradise Island offer a plausible model for deposition of the fossiliferous lenses of the Gilmore City Limestone. Addition of sandy and micritic matrix to the recent shell deposits would produce remarkable similarity to the fossiliferous lenses at Humboldt. The key to understanding the Paradise Island deposits and, by analogy, the fossiliferous lenses of Gilmore City lies in finding a method of deposition that concentrates size-sorted, well-preserved specimens transported from diverse environments. These deposits would have to accumulate at a site where they would remain undisturbed until covered. A backshore location offers greater protection from degradation than channel or tidal flat locations.

The deposits on Paradise Island were strikingly like the Humboldt lenses in the following ways: surrounding matrix, size of specimens, exceptional preservation, abundance of specimens, and diversity of species. It is difficult to attribute the similarity to coincidence. As at Hodge's Quarry, the size of shells could have led to interpretation as a dwarfed fauna, but the Paradise Island specimens were undoubtedly size-sorted. Only the smaller shells were rafted by the small amount of water that broke over the protective barrier and deposited on the backshore. Also, the sharp delineation between the shell deposit and the oolitic sand was duplicated at Hodge's Quarry.

Burial of the Paradise Island shell concentrations could provide an analog for the carbonate coating on the Humboldt fossils. Episodic precipitation from sea water would protect the delicate aragonite markings on the gastropods until the deposit could be covered deeply enough to permit replacement of the aragonite. Dr. Bruce Selleck, (personal communication, 1981) after a trip to Sanibel Island in Florida, conjectured about the Hodge's Quarry material. "...It is likely that the shells were coated while in contact with either water of normal marine composition or of slightly elevated salinity." How then was this to be reconciled with a backshore deposit? "...Perhaps in the Hodge's Quarry setting, the ooid/shell material was driven toward a lagoonal setting by waves. Under exceptionally high wave conditions, the ooid shoal would be built up slightly above sea level so that our mechanism (as on Sanibel or Paradise) could operate. Then, as normal conditions returned, saline waters from the lagoon would percolate through the ooid/shell barrier, bringing about the precipitation we could now see." This would be possible with a backshore deposit on an elevated shoal, or with an island backshore deposit narrowly separated from a hypersaline lagoon.

Crowe and Schneyer (personal communication, 1980) suggested that the fossiliferous strata could have been deposited when the environment was changing from a hypersaline lagoon to an ooid bank. The percentage of ostracode specimens is consistently close to 40% of all the fossils in the lenses; this supports the interpretation made above as ostracodes exhibit a high degree of tolerance for salinity. These fossiliferous lenses could have been deposited on the backshore of a lagoonal island and later covered by deposits of the transgressing ooid banks. Most of the depositional environments necessary to explain the facies of the fossiliferous interval at Humboldt are apparently present on Paradise Island.

CONCLUSIONS

Subsequent burial and cementation of beaches like those on Paradise Island can explain the differing facies at Hodge's Quarry. The calcarenitic limestone with the worn shell clasts at the quarry apparently had a depositional environment similar to the north beach of Paradise Island. Similarly, the oolitic calcarenites whose small lenses contain concentrations of fossils can be duplicated on the main Love and Shell Beaches. The calcarenitic, bioclastic masses probably were the result of tidal flat deposits or a backshore deposit laid down during an intense storm. The fossiliferous lenses would have been backshore deposits.

The deposition of the fossiliferous layer during a change in environment from a hypersaline lagoon to an ooid bank explains the dominance of ostracodes. Variability of the facies within this interval, size of specimens, amount of wear, diversity and concentration of fauna, can be explained by variations of wind direction and velocity, amount of fetch, off-shore slope,and configuration of local land forms. The deposits at Love and Shell Beaches suggest that the variation in the height of the protective shore and in the configuration of the two embayments is most important.

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