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SURFACE TEXTURES OF *NEMASTER RUBIGINOSA* (CRINOIDEA; ECHINODERMATA) SAN SALVADOR, BAHAMAS

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ABSTRACT

The comatulid crinoid *Nemaster rubiginosa* is found off the west coast of the island of San Salvador (Bahamas) in water as shallow as 4 meters. It is abundant enough to contribute ossicles (plates) to the sediment by natural processes.

Arm plates (brachials) and pinnule plates (pinnulars) taken from collected specimens were subjected to laboratory tests of abrasion and dissolution in order to identify the effects of these processes on the echinoderm's stereom. Brachials and pinnulars of *Nemaster* picked from sediment samples were then compared to the test specimens.

Breakage of slender spines is the first recognizable consequence of plate movement. Initial abrasion is indicated by the loss of the large-mesh stereom found on some plates, along with the nearly complete loss of spines. Smoothly rounded plates with polished fulcral ridges result from prolonged abrasion.

Initial dissolution in the laboratory results in a subtle roughening of the stereom's surface. Prolonged dissolution causes enlarged openings in the stereom and sharp-pointed projections. Small solution pits and etched cleavage planes are diagnostic surface details revealed under high magnification.

The plates recovered from the sediment show the effects of abrasion, dissolution, and a range of biologic processes not duplicated in the laboratory experiments. These include localized stereom breakage (bite marks?) and microborings. Plates found in the Pleistocene reef rock exposed on the island demonstrate the potential for future studies of diagenesis using crinoid plates.

INTRODUCTION

In spite of the fact that crinoids were a major component of many shallow marine ecosystems in the geologic past, relatively little research has been done on the taphonomy of modern crinoids. Meyer (1971) and Liddell (1975) documented the rapid rate of skeletal disarticulation in comatulid crinoids at the sediment-water interface, and Meyer (1971) described selective scavenging by the isopod *Cirolana parva.* Within the last five years, research has shown that some fish are active predators of living crinoids (Meyer et al., 1984; Meyer, 1985; Meyer and Meyer, 1986.)

Blyth Cain (1968) laid the foundation for laboratory experiments using crinoid carcasses and skeletal plates. Meyer and Meyer (1986) illustrated separate skeletal plates recovered from sediment samples taken on the Great Barrier Reef and documented their distribution relative to the living crinoids.

The present investigation focuses on the separate plates as sedimentary particles, using laboratory experiments to isolate the effects of dissolution and abrasion on grain shape and surface textures. Our work shows that crinoid plates can be found in Bahamian sediments in sufficient numbers for study even though the living crinoid populations are much smaller than those in the South Pacific. This allows us to compare laboratory observations with the effects of natural taphonomic processes. In addition, we have been able to recover a few crinoid plates from a Pleistocene reef exposed on the island, demonstrating the potential for future studies of crinoid-plate diagenesis. Results to date are summarized below; a larger manuscript, with illustrations, is in preparation.

OBJECTIVES

Our objectives were:

1. To isolate the biostratinomic processes of abrasion and dissolution in the laboratory in order to determine the effects each has on the calcite stereom of a modern crinoid.

2. To examine these effects using the scanning electron microscope and to define diagnostic

surface textures ("signatures") for each process.

3. To apply these diagnostic criteria to Recent and Pleistocene crinoid plates to determine the relative importance of the processes involved in their fossilization.

PART 1. CRINOID PLATES USED AS CONTROL SPECIMENS

Procedures

Whole crinoid specimens were collected by hand using SCUBA in Fernandez Bay at Snapshot Reef and at *Cervicornis* Reef (Telephone Pole Reef), and preserved in buffered formalin. In the laboratory, soft tissue was removed with a solution of chlorox and distilled water.

In order to standardize the elements used in the laboratory experiments, six plate types were defined with a narrow range of morphologic variation and plates were selected which conformed to these norms and which were complete or nearly so.

Results

Each arm of *Nemaster* branches twice to produce a total of 20 arms, and almost every arm plate (brachial) supports one pinnule. Each pinnule contains approximately 23 plates (pinnulars). As a result, one individual crinoid is capable of producing approximately 77,500 separate plates, not counting those formed during arm regeneration.

The six plate types chosen to represent this complex skeleton are listed below:

1. "Small pinnulars"-with 7 or 8 unbroken spines making up a "crown" or "collar" which surrounds a "core" of fine-mesh stereom, and lacking spines on the "shank" of the pinnular.
2. "Large pinnulars"-with 8 or more "collar" spines, commonly fused at their bases, and with small to large spines on the shank.
3. "Small brachials" or "U-shaped brachials"-having a distinctive horseshoe shape, composed mostly of coarse-mesh stereom.
4. "Medium-sized brachials"-with well-developed spines on the aboral margin of facet and with a deep, V-shaped intermuscular groove separating muscle fossae.
5. "Large brachials"-similar to medium-sized brachials, but larger, more elongated, and with smaller spines at margin of facet.
6. Cirrals-both tall and short, with thin rim at periphery of distal facet.

Crinoid stereom (Macurda et al., 1978) is formed by a combination of accretion and resorbtion of previously formed calcite. Accreting ends of the calcite rods which make up the stereom are seen as rounded knobs. The surfaces of the stereom appear smooth at high magnification, except for some irregular pits and microborings at or near the plate margins. Individual plates display repair of injuries by regenerated stereom. Spinose plates commonly have spines with broken tips which are not yet regenerated; some of this breakage undoubtedly took place during collection.

PART 2. ABRASION

Procedures

The primary piece of equipment used in our abrasion experiments was a miniature wave tank consisting of a plastic pan 23cm long, 12.5cm wide, and 4cm deep (Rubbermaid's finest), mounted on roller-skate wheels and driven by a phonograph turntable. A sediment sample taken at Telephone Pole reef was picked to remove all echinoderm grains and 40g of this sample served as the abrasive. The water used was 300ml of buffered sea water (34 parts per thousand). The crinoid plates added to the wave tank consisted of the following carefully examined elements:

Small pinnulars	40
Large pinnulars	40
Small brachials	40
Medium-sized brachials	30
Large brachials	20
Cirrals	40

The wave tank completed 42 cycles per minute, and the grains were observed to move by traction approximately 5 to 15cm on each half cycle, for an estimated transport rate of 4.2 to 12.6 meters per minute.

The wave tank was stopped at intervals and the plates were either <u>sampled</u> (10 specimens of each type were removed and examined), or a complete <u>census</u> was made (all specimens, including fragments, were removed, counted and examined).

Observation Schedule

Interval Time	Elapsed Time	Type of Observation
20 min	20 min	Sample
40 min	1 hr	Census
1 hr	2 hr	Sample
1 hr	3 hr	Census
1 hr	4 hr	Sample
2 hr	6 hr	Census
3 hr	9 hr	Sample
3 hr	12 hr	Census
6 hr	18 hr	Sample
6 hr	24 hr	Census
12 hr	36 hr	Sample
12 hr	48 hr	Census
12 hr	60 hr	Sample
12 hr	72 hr	Census

Results

Diagnostic criteria

Grain morphology:

Some small spines, such as the delicate "collar" spines of small pinnulars, break at the slightest movement, and the amount of spine breakage continues with increasing abrasion. The plates themselves are broken according to definite patterns. For example, after most of the spines of the small pinnulars have been broken off, the remains of the "collar" typically breaks away allowing the fine-mesh "core" to be removed. In some cases, these patterns of breakage allow one to distinguish between breakage caused by abrasion and breakage caused by biologic activity (predators, scavengers, deposit feeders, etc.).

Surface relief decreases and grain outline becomes increasingly rounded. Medium-sized brachials become rounded "buttons" after extreme abrasion. In addition, elements assume their former shapes as the exterior layers of the stereom are worn away, reflecting the importance of the accretionary mode of growth. Nearly cylindrical cirrals become flatter because of preferential wear on lateral surfaces, and extremely abraded pinnulars even reveal former spines (along the shank as well as at the distal end).

Surface textures:

1. Breakage. Spine breakage often occurs during life and with minimal post-mortem transport, but a large number of fractured or chipped rods within the stereom is an indicator of abrasion. Many broken surfaces have rounded or beveled edges.

2. Rounded and polished surfaces. Broken surfaces are blunted, rounded, and polished. Moderate abrasion of brachials results in noticeable polish of the fulcral ridge and surrounding area. Extreme abrasion rounds and polishes other surfaces.

PART 3. DISSOLUTION

Procedures

Slow dissolution

Ten specimens of each of the six plate types were placed in a solution of formic acid with a pH of 3.90. One specimen of each type was removed after ten logarithmic intervals starting at 20 minutes and ending at 170.5 hours.

Rapid dissolution

Specimens were rapidly etched in a solution of hydrochloric acid at a pH of 1.50 for one minute.

Results

Diagnostic criteria

Grain Morphology:

Dissolution affects gross shape less rapidly then abrasion does. For example, brachials retain the V-shaped adoral groove even after the muscle fossae are removed by dissolution.

Surface textures:

1. Pointed terminations of calcite rods. The blunt growing-tips of the calcite rods are sharpened by mild dissolution, and moderate to extreme dissolution destroys continuous rods by severing them at the midsection (the thinnest part). In both cases, pointed projections result.

2. Etched cleavage planes. Visible at high magnification after moderate to extreme dissolution.

3. Dissolution pits. May be difficult to distinguish from microborings, but, unlike microborings, may be found almost anywhere on the plate.

4. Excavated rods. The interior of the calcite rods appears to be more susceptible to dissolution than the outer zone. As a result, extreme dissolution causes hollowing of the rods, forming tubes.

PART 4. RECENT SEDIMENT SAMPLES

Procedures

This part of the study involves sediment samples collected in 1986 at Snapshot Reef and at *Cervicornis* Reef (Telephone Pole Reef) in Fernandez Bay, and a sediment sample taken at a water depth of 90 feet off French Bay. Samples were collected at the uppermost few cm of the sediment with the aid of SCUBA. On average, 5 grams of sediment yielded 1 to 20 crinoid plates depending upon location and grain size sampled.

Results

Crinoid plates recovered from the sediment samples display a wide range of morphologies and surface textures. Some plates are very rounded and polished, duplicating the appearance of the extremely abraded laboratory specimens. Others (even from the same sample) show the diagnostic surface textures of dissolution. However, most plates display evidence for several taphonomic processes, and, for the majority, biologic processes appear to dominate over both abrasion and dissolution. Many plates are broken and worn in ways not predicted by the laboratory abrasion experiments, and some of these show grooves and scratches probably caused by predators, scavengers, and/or deposit feeders. In addition, many plates are partly coated with one or more types of algae(?), whose effects on the stereom are not yet clear. Distinct microborings are present, but inconspicuous on most plates examined to date.

PART 5. PLEISTOCENE ROCK SAMPLES

Procedures

Two Pleistocene reefs on the west side of the island were sampled, Cockburn Town Reef and Sue Point Reef. Rock samples were boiled in Calgon and water, and broken with a rubber mallet. The sediment freed by these methods was washed and screened.

Results

The Cockburn Town reef samples did not yield any crinoid specimens, but some of the samples from the Sue Point Reef contained a few brachials. Diagenetic processes in the exposed reef rock have masked some of the evidence for biostratinomic processes, but at least one plate shows the rounding and polishing associated with extreme abrasion. Most specimens, however, have a very irregular rounded outline possibly caused by diagenetic processes including the activity of the blue-green algae(?) which stain these grains.

GENERAL CONCLUSIONS

Laboratory experiments show that abrasion and chemical dissolution produce distinctive sets of effects on modern crinoid stereom. Aspects of **grain morphology** are most useful in recognizing abrasion--extensive spine breakage and rounding of the plate, as well as distinctive modes of plate destruction. Details of **surface texture** are most diagnostic for dissolution--pointed terminations within the stereom, etched cleavage planes, dissolution pits, and hollowed stereom rods.

These surface textures can be found in crinoid plates recovered from Recent sediment samples, and used to recognize the role played by abrasion and dissolution in the natural habitat. The criteria we define can also be useful in isolating the evidence for biologic activity. Crinoid plates in Pleistocene rocks are rare and their biostratinomic history may be difficult to reconstruct because of the diagenetic overprint.

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REFERENCES CITED

Blyth Cain, J.D., 1968, Aspects of the depositional environment and paleoecology of crinoidal limestones: Scottish Journal of Geology, v. 4, p. 191-208.

Liddell, W.D., 1975, Recent crinoid biostratinomy (Abstract): Geological Society of America, Abstracts with Programs, v. 7, p. 1169.

Macurda, D.B., Jr., D. L. Meyer, and M. Roux, 1978, The crinoid stereom, in R.C. Moore and C. Teichert, eds., Treatise on Invertebrate Paleontology, Part T, Echinodermata 2, v. 1, Boulder, Colorado and Lawrence, Kansas, Geological Society of America and University of Kansas, p. T217-T228.

Meyer, D.L., 1971, Post-mortem disarticulation of Recent crinoids and ophiuroids under natural conditions (Abstract): Geological Society of America, Abstracts with Programs, v. 3, p. 645.

Meyer, D.L., 1985, Evolutionary implications of predation on Recent comatulid crinoids from the Great Barrier Reef: Paleobiology, v. 11, p. 154-164.

Meyer, D.L., C.A. LaHaye, N.D. Holland, A.C. Arneson, and J.R. Strickler, 1984, Time-lapse cinematography of feather stars (Echinodermata: Crinoidea) on the Great Barrier Reef, Australia: demonstrations of posture changes, locomotion, spawning and possible predation by fish: Marine Biology, v. 78, p. 179-184.

Meyer, D.L. and K.B. Meyer, 1986, Biostratinomy of Recent crinoids (Echinodermata) at Lizard Island, Great Barrier Reef, Australia: Palaios, v. 1, n. 3, p. 294-302.