BEACH INDICATORS IN THE MESAVERDE FORMATION

by

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INTRODUCTION

This study is based on research for a University of Wyoming M. A. thesis: "Paleoecological studies in the Mesaverde formation of southeastern Wyoming". Work on the thesis is still in progress. Purpose of the thesis is to make a survey of the different lines of paleoecological evidence available in the Mesaverde formation, the problems involved and the methods for their solution. Emphasis is on a broad coverage of a wide variety of approaches rather than detailed quantitative analysis of a single aspect of the paleoecology. Of a large number of problems investigated and phenomena observed, three were selected for presentation in this paper as they offer the greatest promise for application as environmental criteria and contribution to an understanding of paleogeographic relationships in the Cretaceous. These three criteria are: beach accumulations of *Inoceramus*, modifications of the growth-form of *Inoceramus*, and the crab burrow *Ophiomorpha*, commonly known as *Halymenites*.

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STRATIGRAPHIC RELATIONSHIPS AT REX LAKE

A series of sandstones in the lower part of the Mesaverde formation is well exposed on the west and south sides of Rex Lake (Secs. 26, 27, 34 and 35, T. 16N., R. 77W.), Albany County, Wyoming. These outcrops offer excellent opportunity to study the phenomena to be discussed and to check their reliability as environmental criteria by referring them to a sequence of events and comparing them with other lines of evidence. Since the position of any of the observed phenomena in a sequence of beds of different facies is of great importance, a generalized section for the locality is given below. The emphasis is on the environmental significance of varouis groups of beds.

Mesaverde formation, lower part

	Upper sandstones and sandy shales, undifferentiated.	115′+
Unit F	Sandstone, muddy, mottled with *Anapachydiscus,* other cephalopods and a varied fauna of pelecypods, gastropods and bryozoans.	2.5′
Unit E	Mostly covered; probably mostly poorly sorted mudstone with some siltstone.	175′
Unit D	Sandstone, muddy, occasionally cross-bedded; usually mottled with a rich fauna of cephalopods, pelecypods, gastropods and bryozoans.	27′
Unit C	Transgressive sandstones with considerable lateral facies change.	1.5′
Unit B	Sandstones, buff, usually well sorted with occasional large concretions, often cross-bedded, essentially unfossiliferous with *Ophiomorpha* becoming increasingly abundant in upper few feet.	270′

Steele shale

Unit A	Gray mudstone, poorly sorted with cephalopods and pelecypods. This is the lowest unit exposed.	26′+

The occurrence of *Anapachydiscus* in unit F is significant for detailed stratigraphic correlations. This ammonite is supposed to have a very limited range in the Rocky Mountain region. In the foothills of northeastern Colorado it is diagnostic of the upper part of the Hygiene sandstone member (restricted) of the Pierre shale (Scott and Cobban, 1959). The Hygiene (restricted) is the first sandy unit of the Pierre shale. This suggests that the units B to F inclusively are lateral equivalents of the Hygiene sandstone.

Significant criteria for interpreting the environmental significance of the main body of unit B are the general lack of fossils, the cross-bedding and the clean, well-sorted nature of the sandstones. Broad channels or troughs forming some kind of cut-and-fill structure seem to account for a considerable part of the cross-bedding (Fig. 1-6). This last feature is probably diagnostic for backshore deposits (McKee, 1957). *Ophiomorpha* becomes very abundant in the upper few feet of this unit. The lower 20-30 feet of unit B contain occasional fossils and variable sedimentary features. They represent vari-

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able environmental conditions of a complex nature during initial stages of the regression. The rest of unit B represents beach conditions.

Unit C shows a different development in different outcrops. On the south side of the lake it consists of dark brown concretionary sandstones with local accumulations of *Inoceramus* shells. These shell accumulations are discussed below in considerable detail. Farther to the west the same place in the section is occupied by an olive drab, locally rather brown cross-bedded sandstone. The cross-bedding forms rather low angles to the bedding. This sandstone is quite fossiliferous with the fossils being concentrated at bedding planes, including planes of cross-bedding. Pelecypod shells are disarticulated and orientated with their convex side up. Shark teeth are relatively common in this sandstone.

Unit D is again quite uniform throughout the whole area of outcrops. It is composed of muddy mottled sandstones. Outcrops are rather poor and limited to concretions in the western part and a few lenses of more consolidated sandstones in the south. This unit is generally very fossiliferous. The fossils do not show any pronounced preferred orientation. Many pelecypods are still articulated and some of them are still in burrowing position vertically in the sediment.

From these criteria and the stratigraphic succession the environmental significance of the three units can be interpreted as follows: unit B is a backshore deposit indicating stationary conditions of the beach over a considerable period of time. Unit C represents transgressive forebeach or high-water line deposits respectively. Most of the transgressive deposits have been eroded in the process of readjustment of the beaches as would be expected, but due to a large supply of sediment in relation to the rate of subsidence, parts of the transdeposition in relatively quiet water, therefore some distance below the littoral zone itself. This sequence of beds will serve as a frame of reference by which to relate the different lines of evidence to each other and thereby to check on the consistency of the interpretations given may serve as further checks on the validity of the conclusions to be offered.

ACCUMULATIONS OF INOCERAMUS

The accumulations of *Inoceramus* shells in unit C at Rex Lake possess an abundance of diagnostic features by which they and similar accumulations of shells can be recognized and interpreted. The most important are:

1. Shells of *Inoceramus* are the only fossils found in these shell accumulations. The only exceptions to this rule are known from similar deposits near Rock River where in two places large pieces or logs of fossil driftwood were found in this kind of deposit. Associated with these pieces of driftwood were large numbers of cap-shaped snails of the genus *Anisomyon.*
2. The shells in these deposits were well sorted (Fig. 1-4) and are quite consistently about fist-size.
3. The shells are usually stacked into each other (Fig. 1-5).
4. A considerable proportion of the shells is oriented with the convex side down.
5. A large proportion of the shells has both valves still articulated. Single valves are also common. The exact ration of articulated shells to single valves is impossible to determine because of the hardness of the rock. Broken shell fragments sometimes occur at the top of these shell accumulations where they seem to be limited to a layer of approximately an inch in thickness.
6. Many, if not most of the bivalved articulated shells are gaping (Fig. 1-1). These are usually oriented with the hinge-line at the bottom and the shells opening upward.
7. The whole shell layer is not more than one foot thick and has a limited extent laterally.

These shell accumulations are interpreted as beach accumulations forming along the drift-line on the highest level reached by waves. This interpretation is based on the following considerations:

1. The fact that most of the shells are stacked into each other, often with very little intervening sediment, demonstrates that they have been subject to comparatively strong water movements.
2. The good sorting indicates a rather strong and consistent gradient in the intensity of water movement.
3. The presence of many complete shells indicates that the shells cannot have been subject to strong water agitation for a long period of time. The presence of gaping shells particularly makes a long period of transportation unlikely. A gaping shell would be very unlikely to withstand strong water movement for any length of time. It would not be able to move in a way that might minimize the chances and effects of collision with other objects. At the same time it would have more points or zones of weakness than the more streamlined closed shells or single valves. As a result it would soon become disarticulated or even fractured. Therefore, such

shells must have been deposited very soon after they were picked up by currents or waves. Another interpretation of this phenomenon of gaping shells, and possibly the more likely one is that they represent individuals which were still alive when they were dislodged by the effects of a storm and thrown on the beach. There they died and as a result the shells opened up after they had already reached their place of entombment (Able, 1906, p. 13-14).

A beach is the environment that best fulfills the set of conditions postulated for the formation of these shell accumulations. It has a strong gradient of energy which remains constant in the same position or at least has a constant upper limit for any given intensity of water movement. Underwater situations that might show a similar sudden gradient would not be likely to have it equally consistent. Furthermore they would usually require sediment traps in the form of depressions with very steep sides. Such a situation would be easily recognizable in the field. Sediment traps with these characteristics actually occur in the Mesaverde formation and show very little similarity with the beach accumulations under discussion.

On a beach any object that is moved to the upper limit of water agitation (of an intensity necessary to move the object) would thereafter not be affected by water movements strong enough to damage it. This makes possible the preservation of gaping shells and similar objects.

4. The orientation of shells is another important piece of evidence. However, it is significant only for shells at the bottom of each layer. If any surface is already covered by shells, these will modify the configuration of the bottom and make it uneven so that the stable position of any object is no longer determined by primary factors but by the configuration of the bottom (Richter, 1942).

   Shells moved by waves or currents will assume an orientation convex up as the most stable position (Richter, 1942). In this position they will have a streamlined profile and offer minimum resistance to moving water. Shells falling under the influence of gravity without the effect of lateral water movements will come to rest with the convex side down (Richter, 1942).

   Most pelecypods, no doubt including *Inoceramus,* live either on or in the bottom of the sea. To remove them from the bottom would require currents or wave action. The shells of *Inoceramus* in these shell accumulations are stacked into each other, therefore they can not have lived at their present place of burial and must have been moved in a lateral direction. Where the current or wave agitation decreased along a slow gradient there would always be a point where the water agitation would be no longer strong enough to transport a given shell, but still sufficient to move it into the most stable position. The position convex down is possible only where the water movements come to a sudden stop and the shell comes under the influence of gravity. This occurs only on beaches and in sediment traps. Of these alternatives, the possibility of sediment traps has already been discarded (see above).

   The actual mechanism responsible for turning the shells into a convex down position may or may not involve gravity. A different mechanism involving air entrapment has been observed (Kornicker and Armstrong, 1959). This mechanism also is dependent on beach conditions. The mechanism also is dependent on beach conditions. The preservation of an orientation convex down is in any case governed by the factors discussed above.

5. Large pieces of fossil driftwood were found at two places near Rock River within identical accumulations of *Inoceramus* shells. Beaches are the most likely place for large pieces of driftwood to accumulate. In the normal marine sediments fossil wood occurs in small fragments. In the concentrations of *Inoceramus* shells only two large pieces have been found. This is another argument in favor of a beach origin of these shell accumulatinos.

6. Beach accumulations of this nature form narrow strips on beaches following a certain contour. In outcrop these shell accumulations are discontinuous laterally. No bedding planes have been exposed to a sufficient extent to trace the areal pattern of these shell accumulations. What is at present known about their distribution does not contradict the pattern postulated.

GROWTH-FORM OF INTERTIDAL INOCERAMUS

Many shells of *Inoceramus,* particularly many of those occurring in the beach accumulations just described show considerable irregularities in their growth-form. The most striking and most consistent feature of this type is a sudden bend in the shell. As a result the outer parts of the shell grow more or less at right angles to the plane of occlusion (Fig. 1, 2, 3, 5). Beyond the bend the surface ornamentation and corresponding features on the inside of the shell become very irregular (Fig. 1-3).

Similar bending around the shell has been observed in recent *Mytilus* (Wasmund, 1926) and in some Triassic terebratulid brachiopods (Muller, 1950). In both cases it has been interpreted as a result of periodical exposure to the atmosphere. Periodical exposure to the atmosphere may occur in tideless seas, but for all practical purposes this means an intertidal environment.

There are two different lines of reasoning supporting this conclusion. The first rests on the fact that a pelecypod when it becomes exposed to the air must keep its valves tightly closed to retain a supply of water inside the shell and thereby prevent desiccation. This will keep the mantle in an unusual and probably somewhat strained position for long periods of time. Since the mantle secretes the shell, it is to be expected that the shell too will be affected by this.

With the shell closed the mantle probably would be somewhat retracted. The same would happen to the new shell material being deposited. The end result would be the growth form observed in *Inoceramus.*

The other explantion of this growth-form would involve a consideration of adaptive value. The bend in the shell and growth at approximately right angles results in a greater volume of the shell relative to a normal more compressed form with the same length and height. This would increase the volume of water that an individual of the same size could store in the interior of its shell, certainly a considerable advantage to a marine organism that has to keep its shell hermetically closed for long periods of exposure.

Both lines of reasoning give support to the interpretation of this growth form as a characteristic feature of the intertidal zone. A further argument in favor of this interpretation is the occurrence of *Inoceramus* with this growth form in beach accumulaitons and their absence in the more normal marine deposits.

OPHIOMORPHA

Ophiomorpha is a structure widely distributed in Cretaceous and Tertiary beds over the entire world. A number of different names have been applied to this structure in various regions. In North America it is generally known as *Halymenites.* This usage is based on an erroneous assignment of these structures to a genus of Mesozoic algae by Lesquereux who first described these structures from North America. Essentially all the species in the original description of the genus *Halymenites* including the type species are broad lobate structures from the Upper Jurassic of Germany and probably represent true algae. Ophiomorpha, a name first applied in Sweden, has priority among all the names that are restricted to the forms under discussion (Hantzschel, 1952).

Ophiomorpha is definitely not an algae. It represents burrows of some littoral animal. All evidence points towards a decapod crustacean as the only type of animal capable of forming that type of structures. If one would want to restrict it even more and call them crab burrows it would be very likely a correct interpretation in at least the majority of cases.

Ophiomorpha as it occurs in the Mesaverde formation consists of two parts. One is a vertical shaft which may be more than a foot long and usually does not branch. The second consists of a number of branching and sometimes anastomosing tunnels which are approximately horizontal and cover areas of several square feet. Both shaft and tunnels are about one inch in diameter and have walls built of mud pellets. These mud pellets are spherical and usually made of finer grained sediment than the surrounding sandstone (Fig. 1-7).

Of all marine organisms crustaceans are practically the only ones capable of forming spherical pellets, other groups of organisms lack the appendages with which to form these pellets. Decapod crustaceans are the only group that has species and genera falling into the right size range (Hantzschel, 1952). Mud pellets formed by recent crabs have been figured (Hayasaka, 1935).

Burrowing crabs are common on modern beaches. Their burrows may open to the surface on elevations of 10-40 cm above sea level (Hayasaka, 1935) and may occur considerable distances inland from the high-water line (Pearse, Humm and Wharton, 1942). This agrees with the inferred environment of *Ophiomorpha* at Rex Lake. Most occurrences of *Ophiomorpha* are in smaller lithology and usually in analogous position in a transgressive sequence of beds. Some however occur in sand-

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FIGURE 1

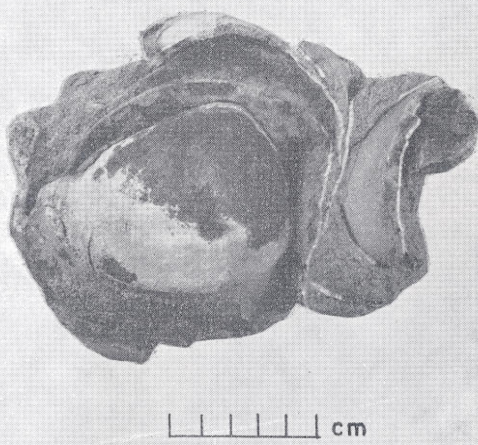
1. **Inoceramus barabini Morton, gaping shell from beach deposit, Rock River, Univ. Wyoming, no. A 11 896.**
2. **Inoceramus sp. showing bend in shell, unit C, Rex Lake, Univ. Wyoming no. A 11 897.**
3. **Same specimen, side view.**
4. **Beach accumulation of Inoceramus shells, unit C, Rex Lake.**
5. **Inoceramus sp., several shells stacked into each other, unit C, Rex Lake, Univ. Wyoming no. A 11 898.**
6. **Top of unit B showing cut-and-fill structures. Hammer rests on contact between unit B and C. Rex Lake.**
7. **Ophiomorpha. The wall formed of mud pellets has weathered out leaving external mold and part of internal filling of burrow. McFadden.**

1

2

3

4



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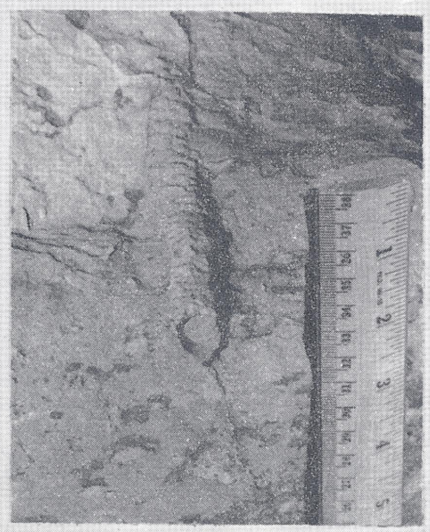

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stones which do not show any recognizable environmental criteria and may or may not represent the backshore environment or the littoral environment.

Structure referrable to *Ophiomorpha* must have been built by a number of different genera and species. The great range in both space and time makes this necessary. It is quite possible that *Ophiomorpha* in the Mesaverde was built by several species with different environmental ranges. Therefore the presence of *Ophiomorpha* should be used with caution in making environmental interpretatinos. Its presence in large numbers in well-sorted otherwise unfossiliferous sandstones would still be suggestive of a beach environment.

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