THE ZONATION OF MODERN ROCKY INTERTIDAL ORGANISMS AND THEIR FOSSILIZATION POTENTIAL, SAINT-YVON, QUEBEC, CANADA

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INTRODUCTION

Rocky shores are common in the world and have been well studied by marine biologists, yet they have been neglected by paleontologists because they have traditionally been thought of as erosional, not life surfaces (Johnson, 1988). Taphonomy, the study of fossilization processes, has recently arisen as one of the primary fields in paleontological research. On the other hand, intertidal zonation has been studied in detail for many years. The amount of work that has been done in this field is overwhelming. My research is unique in that I have combined the study of zonation in the rocky intertidal, and the taphonomic processes acting on the organisms present there.

In my field work, I focused on the organisms that inhabited tidal pools on a wave-cut platform. My laboratory work involved a taphonomic study, trying to determine the relative fossilization potential of the organisms from the tidal pools that contain fossilizable hard parts. Soft-bodied organisms, such as *Fucus* sp. (the prevalent brown alga), would probably not be preserved in the fossil record. I performed a tumbling analysis to determine how long the hard parts of tidal pool organisms lasted relative to one another. For example, it would be important to determine if *Mytilus edulis* (a blue mussel) would last longer than *Littorina littorea* (an herbivorous snail). If I could determine the relative fossilization potential for each of the hard-bodied organisms present in the tidal pools I studied, I might be able to get a picture of what the platform would look like if it were rapidly buried. This is my ultimate goal, to determine what this platform would look like in the fossil record. I would also like to see if intertidal zonation could be preserved in the fossil record. My prediction is that the zonation would break down through the loss of many of the key organisms due to taphonomic processes.

I am approaching this problem from the reverse direction that most paleoecologists would follow. People normally look at the fossil record and try to reconstruct what the living community looked like, while keeping in mind the poor preservation of the fossil record (Durham, 1967). I already know what the living community looks like and I am trying to construct what the fossil record of this community would look like.

METHODS

My field work was done on the northeastern coast of the Gaspé Peninsula, Quebec, Canada. I was working on a wave-cut platform at Pointe à Mimi which is located near the town of Saint-Yvon, about 80 km west of Forillon National Park. I sampled the organisms present in the tidal pools on the platform using a random-stratified quadrat technique (Barbour and others, 1987). This method entailed using a square metal grid, 0.25 m^2 in area, that was divided by wire into 25 equal squares. This grid was placed onto one of our 5 transects at intervals of 10 m along the transect. Counts were then taken of the number of organisms present within the grid, and recorded for further analyses, including a cluster analysis and an analysis of variance. I also used these raw data to construct a rough map of where the major organisms are concentrated on the platform (Fig. 1).

I performed a tumbling analysis of the hard parts of the common hard-bodied organisms I encountered at my field site. The methods I employed in the tumbling analyses were quite similar to the work done by Chave (1964). I used a tumbler having a 1.6-liter capacity, which rotated at about 45 revolutions per minute. I put six rounded siltstone pebbles collected from the field area in the tumbler along with the group of shells I was tumbling. The pebbles ranged in size and weight from 2.5 to 4.5 cm in diameter and 12.8 to 34.2 g, respectively. I also added 1.4 liters of water to the tumbler. I adjusted the pH of this water with sodium bicarbonate to approximate the pH of seawater, about 8.0 (Chave, 1964). I tumbled one shell type at a time, and used as many shells as would fit into a plastic weighing tray, roughly 7 by 7 by 2 cm in volume. The dry weight of the shells and the range in the size of each shell type was recorded before any tumbling began. The shells were tumbled for a total of 80 hr; I stopped tumbling after 1, 5, 10, 20, and 40 hr to monitor abrasion. Every time I stopped the tumbling, I dried the sample in an oven at 105° C. The dried sample was then sieved in a -1.75 Ø sieve, which

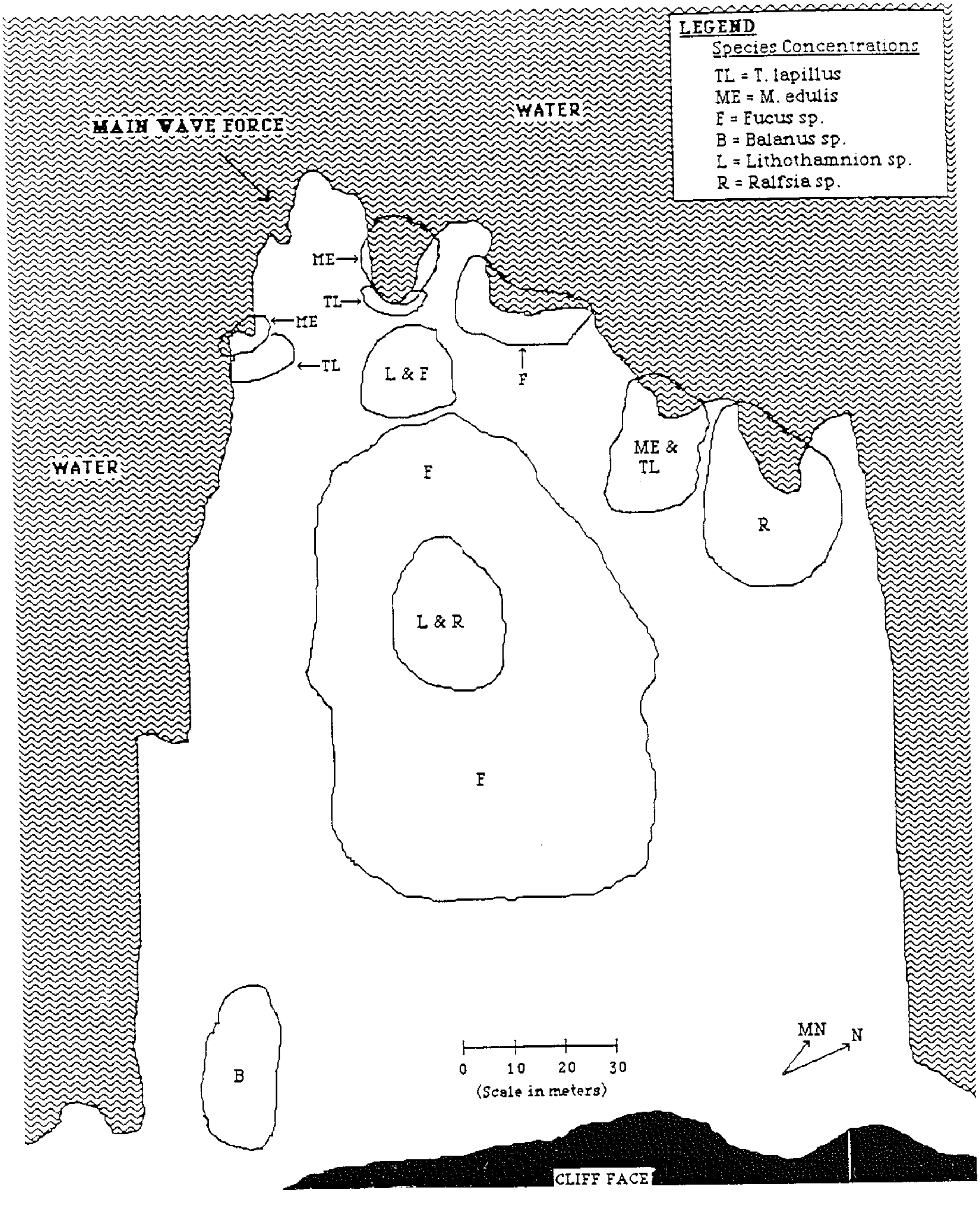

Fig. 1 Map of a section of Pointe à Mimi showing organism concentrations; only those organisms that occurred in dense patches are included here. This drawing was taken from a map that was made with the use of a transit. This is how the platform appears at low tide; it is submerged at high tide.

has a mesh size of 3.36 mm. The portion that did not go through the sieve was weighed on a Mettler balance to the nearest 0.1 g; the finer part of the sample was also weighed as a check to see how much material was lost in suspension. I calculated the weight percent of the sample larger than 3.36 mm as a fraction of the starting weight of the sample. The weight percents of the coarse fraction of the seven shell types were compiled and graphed versus time (Fig. 2).

In addition to this quantitative analysis, I recorded qualitative observations, such as which parts of the shell were eroding first and how many remained whole at each time period. I also took photographs of the shells after various lengths of tumbling time in order to document drastic changes in shell appearance.

RESULTS

M. edulis and *Thais lapillus* (a carnivorous snail) occurred in highest concentrations near the edge of the platform (Fig. 1). The different *Fucus* species occurred at different places on the platform; for example, *F. edentatus* was abundant near the edge of the platform whereas both *F. spiralis* and *F. vesiculosus* were very common on the interior of the platform. I have lumped the latter two species under *Fucus* sp. because they are difficult to distinguish from one another. *Balanus* sp. (acorn barnacles) are scattered over the platform in low concentrations, with the exception of a small area near the southern tip of the platform (Fig. 1). *Lithothamnion* sp. (an encrusting calcareous alga) is relatively common on the platform, and occurs in a couple of dense pockets, usually in association with *Fucus* sp. *Ralsia* sp. (another encrusting alga) is distributed similarly to *Lithothamnion* sp., except for one concentration near the edge of the platform.

Other species that were common on the platform, but didn't occur in dense patches, include *L. littorea*, *L. obtusata* (smooth periwinkle), *L. saxatilis* (rough periwinkle), *Acmaea testudinalis* (tortoise-shell limpet), *Buccinum undatum* (dog whelk snail), *Hiatella arctica* (rock-boring clam), and *Ulva lactuca* (a green alga).

There were only two identifiable zones in the intertidal region of the platform: the *M. edulis* /*T. lapillus* zone near the fringe of the platform; and the *Fucus* sp. dominated zone, which included abundant *Lithothamnion* sp. and *L. littorea* .

Figure 2 illustrates the results of my tumbling analysis. I was unable to do a statistical comparison of the different curves, but there appear to be two distinct groups of curves. The four organisms that lasted the longest in the tumbler included all three snails, and *Lithothamnion* sp. The other set of curves included 2 bivalves and the limpet.

I noticed that the columella was the most resistant part of the snail shells. The periostracum of both bivalves was more resistant than the rest of their shell material. The limpet weathered from the edges in, and the one limpet that was encrusted by *Lithothamnion* sp. lasted far longer than the others. *Lithothamnion* sp. weathered much like a carbonate rock would: it broke down into smaller pieces and then began to get rounded and spherical in shape.

DISCUSSION

The two intertidal zones that I identified at Pointe à Mimi are the *M. edulis* /*T. lapillus* lower zone, and the *Fucus* sp. dominated upper zone. Other zones are visible on the platform, but they are not in the intertidal. The subtidal fringe bordering the platform is dominated by *Laminaria* sp. and *Alaria* sp., both are kelp species. An area along the vertical cliff face (Fig. 1) contains a small supratidal zone of *Enteromorpha* sp. (a green alga). The diversity of the platform might be affected by the lower salinity of the water, which contains roughly 22 parts per thousand at Saint-Yvon, versus 35 parts per thousand in normal marine water.

In my study of the fossilization potential of the organisms present on the platform, my first step was to eliminate all of the soft-bodied organisms from consideration. The numerous brown and green algae would have almost no chance of being preserved in the fossil record because they have no preservable hard parts. Hence, the *Fucus* sp. dominated zone would not contain *Fucus* sp., if the platform were preserved in the fossil record. This zone would probably be dominated by the resistant *L. littorea* and *Lithothamnion* sp. In contrast, the *M. edulis* /*T. lapillus* zone would have a pretty good chance of being preserved, with *T. lapillus* being the dominant organism preserved.

Overall, the pelecypods have a very low fossilization potential. The most resistant part of their shells is the periostracum, which would probably be decomposed by microorganisms due to its organic nature. Limpets also

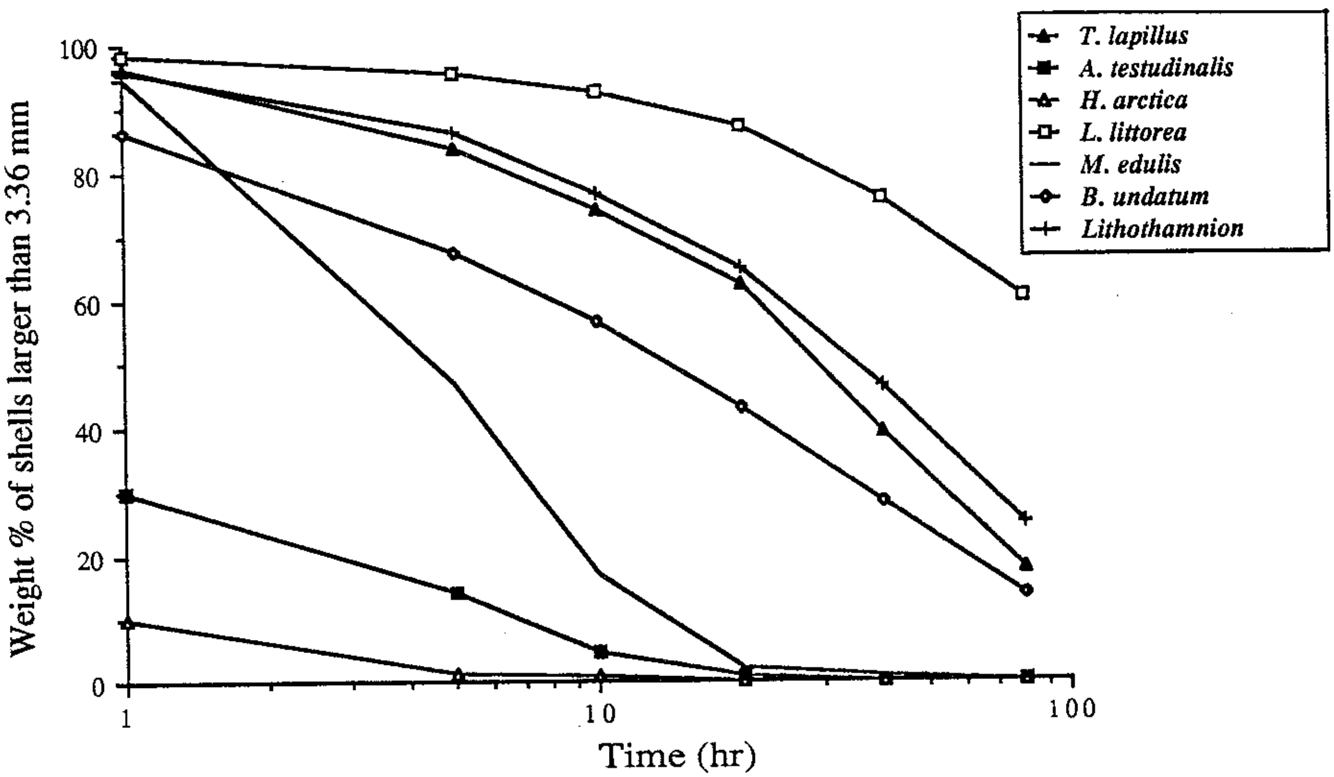

Fig. 2 Weight percent of shells larger than 3.36 mm vs. time. Seven different shell types (listed in the legend) were tumbled for up to 80 hr each.

have a low fossilization potential, unless they were fortunate enough to be encrusted by *Lithothamnion* .

The three snails (*L. littorea, T. lapillus,* and *B. undatum*) had relatively high fossilization potentials, and so did the calcareous algae (*Lithothamnion* sp.). Columella fragments from the snails would probably be over-represented in the fossil record, relative to other snail shell fragments. *Lithothamnion* does not show a trend in abrasion pattern.

There are three main factors in taphonomic analyses: abrasion, dissolution and transportation. My taphonomic analysis took into account only one of these three main factors. I was testing to see how differential erosion affects the fossilization potential of the hard-bodied organisms from the tidal pools. I did not take into account the process of dissolution. Young and Nelson (1988) described how dissolution of shells can occur on cool-water shelves, especially if the shells have been bored. Many of the shells at Pointe à Mimi had been bored, so the possibility for dissolution is at least fair. Flessa and Brown (1983) discussed how shells of differing compositions dissolve at different rates; calcitic hard parts dissolve faster than aragonitic ones. This would have a radical effect on the shells that would be left in the fossil record. For example, the snail shells were quite resistant to abrasion, but they were often bored and might not be so resistant to dissolution in sea water. Transportation is the third factor affecting fossilization potential. In order for organisms to be preserved within a fossil community, they must be preserved in situ (Lawrence, 1968). I did not take transportation into account in my research.

Another problem that I encountered while doing my tumbling analysis was the shrinking of the siltstone pebbles due to abrasion. They shrank in overall weight from 136.9 g to 95.3 g after being tumbled for 560 hr. This means that the shells tumbled towards the end of my experiment may not have received as much force from the pebbles as those that were tumbled at the beginning. I do not think this had a large effect on my results, because there is also weight in the tumbler from the other shells. In other words, not all of the abrasion was due to the pebbles.

I also have to keep in mind the fact that I studied this platform only during one season of the year, summer. The severe storms of winter might have a radical effect on the species distribution. Dethier (1982) found that tidepool algae in Washington state have different distributions depending on the time of year. Changing temperature and light conditions may set the upper limit of the algae, whereas herbivory plays a bigger role in algal zonation.

To conclude, two zones were identifiable in the rocky intertidal at Pointe à Mimi: a lower zone (*M. edulis /T. lapillus*), and an upper zone (*Fucus* sp. dominated, with abundant *L. littorea* and *Lithothamnion* sp.). The lower zone has a good chance of being preserved, with *T. lapillus* being the dominant fossil type. The upper zone would not have as good a chance at being preserved; however, *L. littorea* and *Lithothamnion* sp. would be well preserved and might appear as a zone in the fossil record. I should again mention that I took only abrasive action into account in my study; when dissolution and transportation are taken into consideration the results might look quite different.

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SEDIMENT DISTRIBUTION ACROSS A WAVE CUT PLATFORM, POINT MIMI, ST. YVON, QUEBEC

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The beach at Point Mimi, St. Yvon, is forming over a wave cut platform. The bedrock underlying the wave-cut platform is upturned turbidites. Some of the wave cut platform, which is composed of turbidites, is completely obscured by sediment, while other parts are exposed bedrock. Clasts of shale and sandstone, plus the hard parts of rocky shore biota, collect in tide pools between sandstone ridges and near the base of cliffs.

Point Mimi represents a potential angular unconformity, if the overlying sediment were to be lithified. Most unconformities in the geologic record can be studied only in cross section, and are rarely examined as a rocky shore horizon. By studying an unconformity in the making (i.e., a modern rocky shore), the map view can also be studied, perhaps resulting in a clearer picture of what a fossilized rocky shore looks like, and of how this particular type of rocky shore will be preserved.

METHODS

Sediment, shell and rock samples were collected from 153 surveyed points on the Point Mimi platform. Point counts were performed on thin section of impregnated sediment samples. The results were mapped in terms of percent and total distributions of grain types.

RESULTS

The distribution of grain types across the wave cut platform has a definite pattern. Distinct biofacies exist; the biogenic fragments strongly resemble the patterns of their living counterparts. The death assemblages are, however, more homogenous than the living assemblages. Hard parts are susceptible to wave and current activity, whereas living organisms have specific niches. The biogenic fragments decrease gradually away from the living environment, while the niches sometimes cease abruptly.

About 50% of the platform's lithics consist of shale; 10% consist of sandstone fragments. Lithofacies are similar in that the proportion of fossil fragments to sandstone and shale fragments is more or less constant. The high populations of gastropods, *Stronglyocentrottus*, and *Mytilus* on the platform suggest that their remains should be high in frequency, but none of the groups are present at more than 20% in any given area (figure 1). Gastropods are almost nonexistent in thin section; this may be due to their resistance to breakage.

What is present in the sediment is *Ensis* fragments. *Ensis* lives in sandy environments. *Ensis* fragments dominate the shell distribution across the platform, ranging from 20% to 42%. The proportion of *Ensis* fragments decreases away from the bay (figure 2c), but still holds a high percentage (figure 1).

CONCLUSIONS

The postmortem transport of rocky shore biota is not great. A rocky shore, unlike a beach or lagoon environment, is restricted to its original geographic position. The biota can not migrate beyond the rocky shore environment due to their specialized niches, and the biogenic remains rarely extend far beyond the Point Mimi platform. A rocky shore is commonly buried by beach sediment, resulting in isolated preservation. Few remains of the wave-cut platform biota are found on the adjacent beach more than 50 meters away from the platform.

Point Mimi's fossilization potential is not high, but many of its characteristics are very similar to ancient rocky shores in the literature. MacDonald (1976) found postmortem transport minimal, and the live-dead correspondence high. In the Deschambault Formation of the Trenton Group (a Paleozoic rocky shore deposit in Quebec), little *in situ* material was found, but much rocky shore material was present. Unbroken gastropods and fragments of echinoderms, arthropods and brachiopods also occur in the Deschambault Formation. Zullo, and others, (1987) describe a Pennsylvanian angular unconformity