SHELLY DETRITUS AS A PALEOCURRENT INDICATOR: A MODERN EXAMPLE FROM THE GASPE PENINSULA, QUEBEC

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Introduction

One problem with reconstructing ancient population distributions is that the vast majority of fossiliferous rock is made up of sand sized and smaller grains, while most reconstructions are based on whole fossils or large fossil fragments. In this report I propose a method by which populations can be reconstructed and an oscillatory flow paleocurrent deduced by analysis of the shelly debris "fans" which I hypothesise should be created on the lee side of a population.

This paper is divided into two sections. The first is a theoretical argument for the existence of debris fans. The second shows the results of a field study on modern sediments from a wave-cut platform near Cloridorme, Quebec. This study focuses on the population and debris distribution of the gastropod *Littorina saxatilis*, the rough periwinkle. *L. saxatilis* was used for this study because of its relative abundance on the platform and because of the relative ease with which its sediments can be distinguished from those of other organisms inhabiting the platform.

Theoretical Studies

Komar and Miller (1975) show the relationship between particle size and entrainment velocity under oscillatory flow (Figure 1). Settling velocity for large grains is given by Rubey (1933) as:

$$V=\frac{\sqrt{\frac{4}{3}g\rho_f(\rho_p-\rho_f)r+9\eta^2}+3\eta}{\rho_f r} \quad (1)$$

where V is the settling velocity, g is gravity, rho_f is fluid density, rho_p is particle density, r is particle radius, and eta is the fluid coefficient of viscosity. By plotting the solution to this equation on Komar and Miller's diagram, it is apparent that not only are small (non-cohesive) grains more likely to be entrained than larger ones, but also that small grains will travel farther before being deposited than will large grains. Since grains will travel in the direction of current flow, the result of current passing over a sediment source (like a population of organisms) is a fan grading from coarse to fine in the downcurrent direction.

Chave (1962) reports that grains will disintegrate with time exposed to a wave train. Given this, even a relatively homogenous population will produce debris that will fragment with time in transport, thus disintegrating to smaller sizes, and again forming a sediment fan.

Field Study

Method

I conducted an experiment to study the usefulness of this method on a wave-cut platform on the north shore of the Gaspé Peninsula in Quebec. The purpose of this experiment was to determine if small populations of relatively homogenous organisms (in this case, *Littorina*) do, in fact, produce debris fans that can be observed and quantified to any degree. This experiment focused primarily on the coarsest fraction of sediment available (-2 phi and -1 phi) because these sizes were the most easily identified.

The study area for this experiment was a small (100m x 200m) wave-cut platform on the south bank of the St. Lawrence estuary near Cloridorme, Quebec (Figure 2). The platform is composed of a thinly interbedded turbidite, with beds ranging in thickness from <1cm to 25cm. The beds were oriented roughly perpendicular to the shoreline. The platform is bounded to the south by a rocky cliff, and on the other three sides by medium sand.

overlain by a Cretaceous conglomerate dominated by biogenic material. Were Point Mimi's wave-cut platform deposits to lithify, it would be similar. The deposits lie across an unconformity, the biota experiences little postmortem transport, and the rock formed would have a high percentage of animal hard parts. This modern rocky shore can give an accurate picture of how similar rocky shores developed in the past.

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There is a small stream running obliquely across the platform, discharging approximately 1.2 m^3/sec. Its thalweg is seasonally inundated by winter storms which dredge sediment from the beach into the stream channel. Discharge from the stream is generally low, except during the spring when snow melt greatly elevates discharge.

I examined the shell composition of sediment found on and near the platform, by collecting sediment every 20m along sixteen transects spaced 10m apart. At each collection site I collected 325ml of sediment. In each case, if 325ml were not available, no sediment was collected--if 650ml were available, that amount was collected. No sediment larger than pebble sized was collected. Using the same transects and a 10m distance along each transect, I counted the organisms present at each site in 5 random 0.2m x 0.2m squares in a 1m x 1m grid centered on the transect.

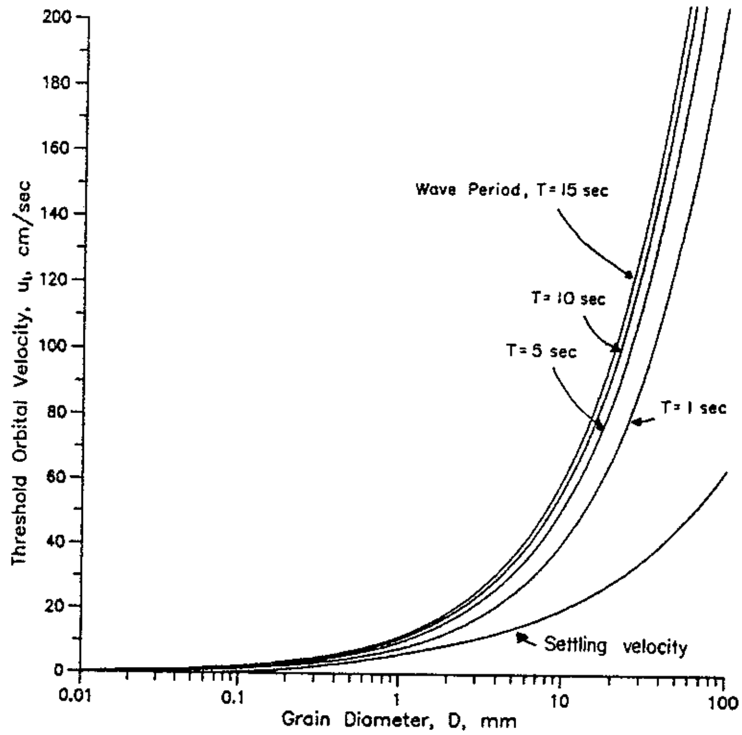

Figure 1 The wave period and near-bottom orbital velocity required for motion of sediment with grain diameter D and density=1.66 g/cm³ (*Littorina*). (After Komar and Miller, 1975)

After air drying the sediment samples for two weeks, I removed a 500g aliquot from each sample. I rinsed each aliquot with 250ml of distilled water to remove any salt, then dried each sample for 12 hours in a drying oven at 60°C. When the samples had been dried, I weighed each sample and then sieved each in a sieve stack of 3,10,18,35,60, and 120 mesh. After sieving, I separated out the *Littorina* debris and weighed that fraction for each site.

Results

The results of my field work are presented as Figures 3, 4, and 6. Figures 3 and 4 show the weight distribution in grams of -2 phi and -1 phi *Littorina* debris, respectively, on the platform, whereas figure 6 shows the population density of *Littorina* on the platform. The outline of the platform at mean low tide and mean high tide is superimposed on each image to serve as a reference.

There are three distinct *Littorina* debris fans in Figures 3 and 4. The first is at the extreme lower left of both figures. The second is located at the far left halfway out the platform, and the third is located in the center of the platform. All three have been marked by transect lines showing their directions. These fans are, I believe, the debris fans which should arise from a combination of Rubey's and Komar and Miller's equations.

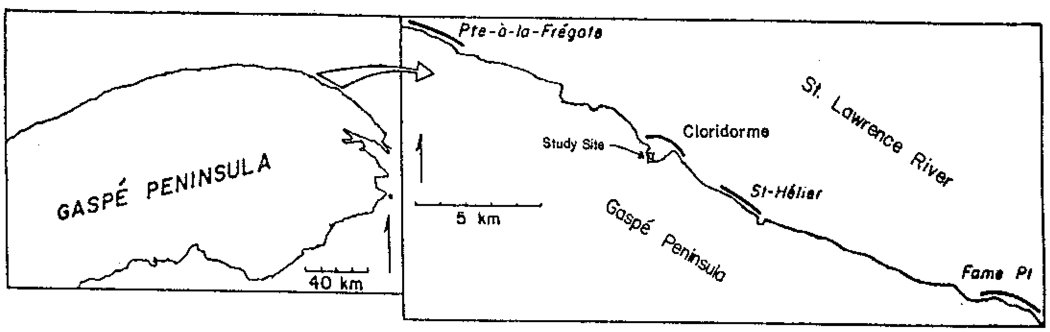

Figure 2 Location of the study site near Cloridome, Quebec. (After Pickering and Hiscott, 1985)

Discussion

If my hypothesis is correct, the three transect lines should fine in the downcurrent direction. All three lines face in different directions, so clearly some explanation is needed to resolve these three separate current indications.

The first fan shows a net current directly out to sea. The area surrounding this fan is riddled with other coarse debris in a band, all of which fines out to sea. On the basis of this, I believe this first fan represents a storm deposit. A storm (such as the summer storms encountered during this study) could easily move a large quantity of coarse sediment onto shore, then winnow off the slightly smaller fraction as storm waves receded.

The second fan shows a net current to the northeast across the platform. One branch of the stream outlets here, discharging approximately one third of the main channel ($4x10^{-2}$ m^3/sec) through a relatively small rock channel (approximately $2m^2$). While this discharge alone is insufficient to generate the current necessary to move -1 phi sized grains, the fact that this channel also acts as a drainage conduit for a large part of the platform during low tides should easily produce the required discharge to move the smaller fractions (-1 phi and smaller) a short distance downstream. This probably moved the -1 phi peak a little bit farther out the platform, and the actual current runs a bit further to the east.

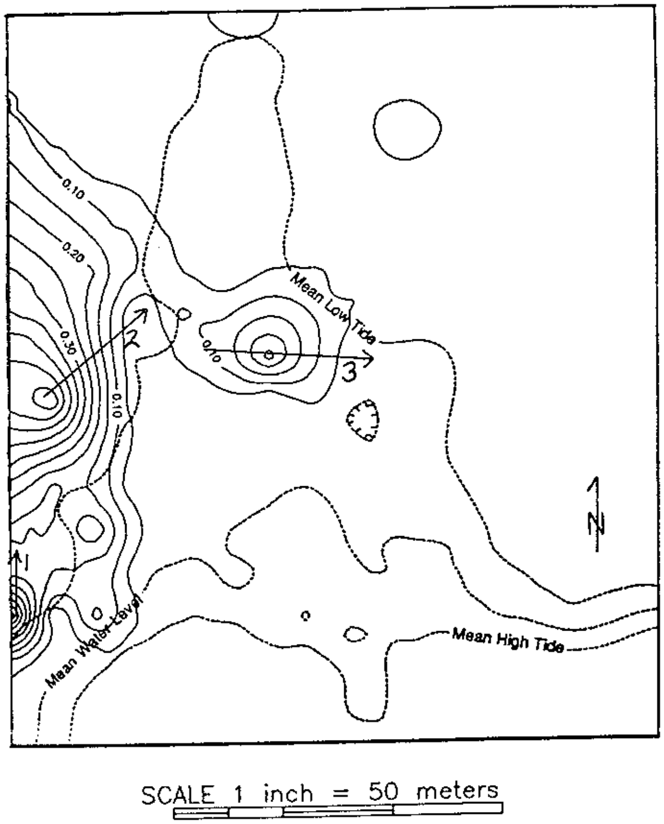

Figure 3 Distribution of -2 phi sized *Littorina* debris on Cloridorme platform. Contour interval .05 grams.

The last fan represents the most probable fair-weather oscillatory current direction. There is no stream activity in this area, and the peaks are specific to *Littorina* alone, so stream and storm activities can be ruled out. A cross section of this transect shows that -2 phi debris is well separated from the -1 phi debris (Figure 5). A final check on this is to compare it with the actual Littorina populations. If this transect represents a debris fan, it must have a population as its source. A quick look at Figure 6 shows that this fan does indeed have a large *Littorina* population as its sediment source.

A plot of *Littorina* population density along the transect is given as Figure 7. Given this data, it is possible to make a maximum estimate of the fair-weather current velocity in this area. If I assume that the particles were carried to their final position in one hop (not likely, but it does put an upper constraint on the velocity), without being re-entrained at any time, I can get a maximum possible current. The settling velocity for a -2 phi sized (4 mm) particle is given by Figure 1 as 9.87 m/sec. If I know the height of the particle above the bed at the time it was entrained, I would be able to compute the time in transport from the settling velocity. *L. saxatilis* has the advantage of living on crags just above high tide, so the height can be assumed to be the difference between high tide and the bottom (in this case, about 30cm). Given this height estimate, the particle can be assumed to have travelled for about 3 sec. before coming to rest on the bed. If I know how far the particle travelled horizontally in that time, I have an estimate of the maximum possible velocity for that area. From Figures 5 and 7, I can see that the distance is about 10m. From this, I conclude that the maximum velocity on the platform is about 300 cm/sec. The minimum velocity is constrained by the fact that -2 phi debris did, in fact, move. That velocity is given by the settling velocity for -2 phi sized *Littorina* debris and is shown on Figure 1 as approximately 10 cm/sec.

A more accurate constraint of velocity would be possible by comparing the distances from the population of -2 phi and -1 phi particles, assuming that the -1 phi particles were derived solely from the disintegration of the larger particles. In this case, it would not be necessary to know where the particles originated from, but it would be necessary to know the rate at which particles disintegrated. Until this data becomes available, this method remains a theory.

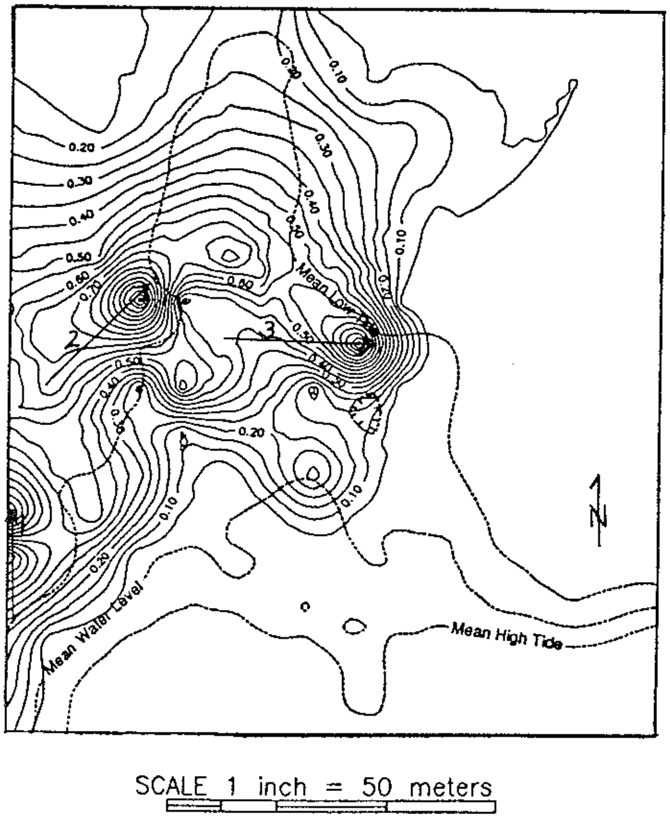

Figure 4 Distribution of -1 phi sized *Littorina* debris on Cloridorme platform. Contour interval .05 grams.

Summary

On the basis of my field studies, I conclude that debris fans are produced by populations of organisms, and that these fans fine in the downcurrent direction. However, there are more pitfalls to analysing these fans than I originally thought, including:

1. Sediment traps which collect coarse debris.
2. Storm deposits.
3. Localised movement of sediment by streams.

Overall current direction is obtainable by this method, and overall current velocity is estimable in this instance. Obtaining velocity estimates without knowledge of the position of the original sediment source relies on a disintegration constant, which will have to be worked out through experimentation. Original population density also involves this constant, and so is also unquantifiable at this time. This method does seem useful for determining oscillatory paleocurrent and population densities of ancient environments, especially those leaving only sandy remains, but disintegration constants must be formulated for organisms before this is possible.

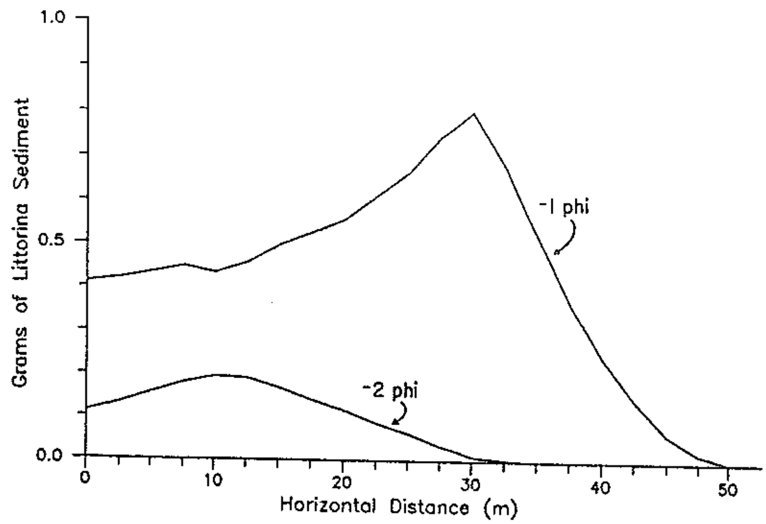

Figure 5 Distribution of coarse *Littorina* sediments along the transect.

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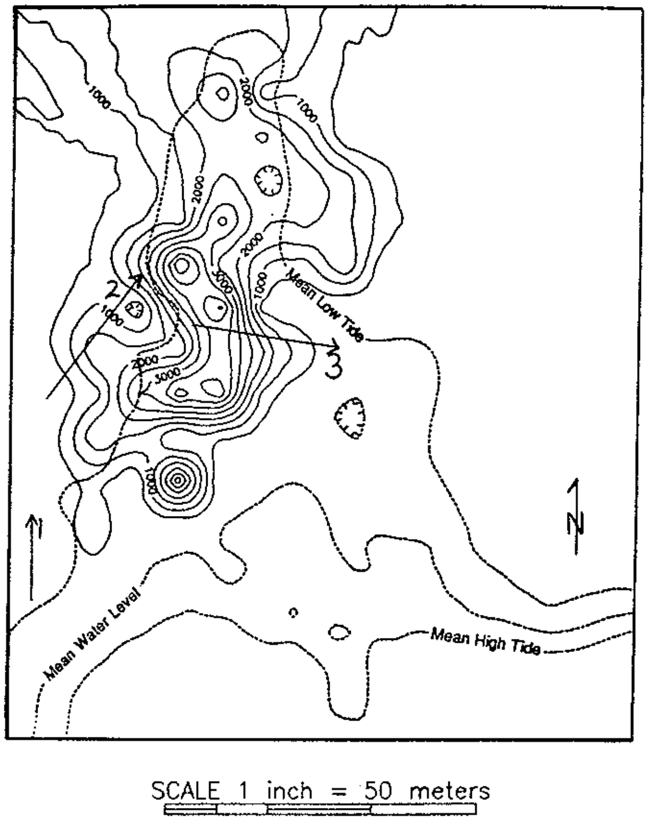

Figure 6 *Littorina* population distribution on Cloridorme platform. Contour interval 500 individuals/m².

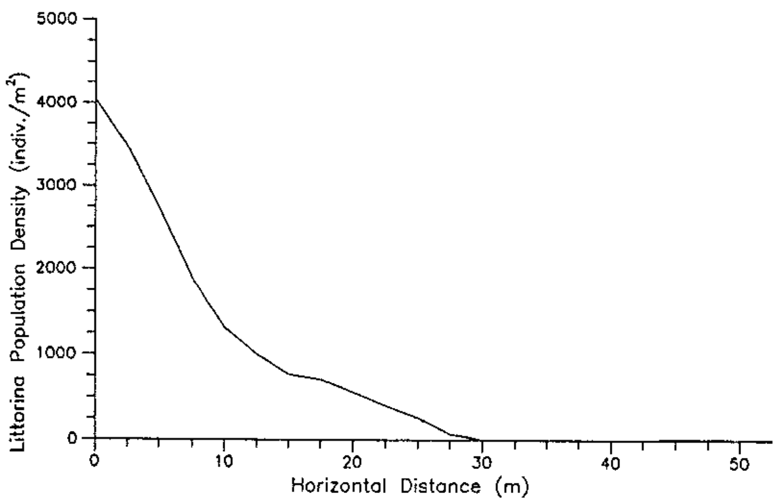

Figure 7 Distibution of live *Littorina* along fan 3.