The Distribution of Trace Fossils in Response to Tidal Range

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Ongoing research in ancient and modern sedimentary systems is sponsored by:

- **Natural Science and Engineering Research Council of Canada (NSERC)**
- **BP (Bryan Ireland)**
- **Devon Energy (Dennis Meloche)**
- **Nexen Energy (Dale Leckie)**
- **Talisman Energy (Dave Mundy, Gary Labute, Jason Lavigne)**
- **Petro-Canada (Richard Evoy)**
- **ConocoPhillips (John Suter)**
- **Imperial Oil (Stan Stancliffe)**

*Special thanks to Dalrymple, Pemberton, and Reinson.*
SUMMARY

• Trace fossil distribution is primarily a function of hydraulic energy (+ grain size) and water chemistry (primarily salinity and oxygenation).
• Salinity and hydraulic energy change predictably in marginal-marine settings, primarily as a function of fluvial input and tidal range.
• Hypothesis: the degree of tidal influence in a depositional environment can be assessed by the distribution of trace fossils.
Hydraulic conditions change predictably in estuaries.

Dalrymple et al, 1992
The Energy Distribution in Estuaries Leads to:

• In part determining whether or not an estuary will be vertically or laterally stratified.
• Determining the residence time of water within estuaries.
• Influencing the distribution of sediment grain sizes.
• Influencing the location and breadth of the turbidity maximum.
### The Influence of Tidal Range

<table>
<thead>
<tr>
<th>Tidal Range</th>
<th>Nature of Stratification</th>
<th>Water Residence Time</th>
<th>Nature of Grain Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microtidal</td>
<td>More Vertically stratified</td>
<td>Months in Inner Estuary</td>
<td>Tripartite</td>
</tr>
<tr>
<td>Mesotidal</td>
<td>Seasonally Variable</td>
<td>Weeks in Inner Estuary</td>
<td>Sand-rich into Middle Estuary</td>
</tr>
<tr>
<td>Macrotidal</td>
<td>Laterally Stratified</td>
<td>Days to Weeks??</td>
<td>Sand-rich with Muddy Bay Margins</td>
</tr>
</tbody>
</table>

Stratification in estuaries is a result of fresh water being more buoyant than salt water.
Where turbulence is increased due to high tidal exchange or as a result of meteoric storms, estuaries become less stratified.
Water retention in bays and estuaries results in lower landward salinity and a reduction in the dissolved O$_2$.

Willapa Bay changes about 40% of its water every tidal cycle!
If we make the statement that hydraulic energy mainly controls the distribution of trace fossils and chemistry mainly controls the size and diversity of trace fossils, we can make some good assumptions regarding the nature of trace fossil assemblages in bays and estuaries.
Dalrymple et al, 1992
Example of a predictive model: tide dominated.
Example 1: Willapa Bay

- Upper mesotidal but wave-dominated.
- Up to 43% of bay volume exchanged in a tidal cycle.
- Shows a well defined salinity gradient once in inner estuary.
- Shrimp Burrowed
- Nereis Burrowed
- Thread worm Burrowed
\[ F(x) = \text{diversity} \times \text{diameter} \]
F(x) = diversity x diameter
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\[ F(x) = \text{diversity} \times \text{diameter} \]
Example 2: Tillamook Bay

- Mid-mesotidal: wave-dominated.
- Up to 30% of bay volume exchanged in a tidal cycle.
- Shows a well-defined salinity gradient only in inner estuary.
- Shrimp
- Bigger Worms
- Smaller Worms
Example 3: Ogeechee Estuary

- Lower-mesotidal: wave-influence minor.
- Up to 25% of bay volume exchanged in a tidal cycle.
- Has more notable fluvial input than Willapa or Tillamook.
- Shows a well defined salinity gradient throughout estuary.
Ogeechee / Ossabaw Sound shows progressive increase in size and diversity basinwards. In general, bioturbation intensity is highest in the inner third of the estuary.
Example 4: Bay of Fundy in General

- Macrotidal: wave-influence minor.
- Huge tidal prism.
- Fluvial inputs absolutely overwhelmed by tidal waters.
- Salinity gradients minor, except in estuary arms.
High-energy tidal currents in the Bay of Fundy lead to a lack of burrowed facies except near bay margins and in sheltered flats.
Essentially, no ichnological gradient is observed within bay. All the red zones shown below display the same ichnocoenose. The hatched area opens into marine conditions but is too energetic for much colonization to occur.
Macrotidal Example

From M. Ranger.
The Influence of Tidal Range

<table>
<thead>
<tr>
<th>Tidal Range</th>
<th>Distribution of Trace Fossils</th>
<th>Size of Trace Fossils</th>
<th>Diversity of Trace Fossils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microtidal</td>
<td>Follow Tripartite Zonation, Abrupt Ichnofacies</td>
<td>Generally Small in Middle Estuary</td>
<td>Generally Low Diversity in Middle Estuary, Impoverished or Absent in Inner Estuary</td>
</tr>
<tr>
<td>(not tested in modern)</td>
<td>Mappable and Gradational Boundaries, Rarely Burrowed Inner from Outer to Inner Estuary</td>
<td>Gradually Decrease in Size Towards Inner Estuary</td>
<td>Gradually Decrease in Diversity Towards Inner Estuary</td>
</tr>
<tr>
<td>Mesotidal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macro tidal</td>
<td>Little Variation in Ichnofacies</td>
<td>Unknown</td>
<td>Generally Low due to Hydraulic Reworking</td>
</tr>
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<td></td>
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</tbody>
</table>

- Little Variation in Ichnofacies
- Unknown
- Generally Low due to Hydraulic Reworking
Summary

• Ichnofossils likely provide a means of determining the magnitude of tidal influence that a depositional setting was subject to.
• In general, only mesotidal settings offer gradational ichnofacies subdivisions.
• Microtidal should be mostly burrowed in the bay center—probably with sharp transitions demarcating the tripartite facies zonations.
• Macrotidal estuaries show no obvious ichnological gradients.
• The dataset needed to analyze a particular interval needs to be quite large.

Thanks!