A Novel Database-Driven Approach to Shallow Marine Classification: Towards Building a Knowledge Base*

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Abstract

Classification systems that are widely used in sedimentary geology meet the following criteria: (i) they are relatively simple and based on a limited number of variables; (ii) they tend to be shown as two-dimensional diagrams; (iii) they attempt to resolve a practical problem. The output of these classifications is placing the variability of the natural world in discrete categories, which ideally show sufficient commonality in properties and behavior. Since shallow marine systems are often described on basin and local scales, different classification systems are applied to the same package of rock. Sequence stratigraphy, which can be thought of as a classification system based on accommodation change and sediment supply as input variables and systems tracts as output categories, tends to be applied to studies examining basin-scale modes of deposition. Studies focused on local facies variability, on the other hand, usually take a depositional systems approach. They use one of several available process-based classifications, based on waves, tides, and fluvial sediment supply as key variables, and process domination as output categories. Use of separate classification schemes for basin-scale and local deposition deals poorly with the often existing co-dependence between the two.

We propose a new classification scheme for shallow marine systems that utilizes a database-driven approach. In comparison to conventional paper-based classification schemes, database-driven classification can handle numerous variables without compromising ease of use. The new classification system is based on variables that are measurable in the ancient record: (i) wave facies influence (ii) tide facies influence, (iii) fluvial facies influence, and (iv) local accommodation (near-shore water depth)—related to parasequence thickness, (v) grain size. Local accommodation, which has not been previously incorporated in classification schemes, is added because of its first order importance on wave and tide energy, rate of shoreline progradation, and degree of preservation of fluvial
influence. The classification can also be enhanced by other variables such as basin type and shelf width. The classification scheme then places the observed depositional systems in distinct categories with assigned primary (e.g., wave-dominated) and a secondary (e.g., tide-influenced) descriptors. The proposed classification scheme is part of a shallow marine knowledgebase currently under development.

References


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WAVE Consortium
University of Adelaide

AAPG Annual Convention 2010
“Classification” Simplified

Complex Multivariate System

Practical Requirement
- Connectivity
- Flow units
- Distribution of baffles and barriers
- System evolution
- Others

Classification

- Usually involves categorization of some type
- Usually focuses on only few aspects of the complex system

Mitchell River Delta, Northern Australia
What about marginal marine system classification?

1) Several choices of classifications available
2) All concentrate on 3-4 variables
3) Use simple diagrams

4) Focus on either large scale (basins, processes) or small scale (depositional systems, facies)

Posamentier and Allen (1999)
Galloway (1975)
**Classification Categories**

- **F** – Fluvial dominated
- **Fw** – Fluvial dominated, wave influenced
- **Ft** – Fluvial dominated, tide influenced
- **Fwt** – Fluvial dominated, wave influenced, tide affected
- **Ftw** – Fluvial dominated, tide influenced, wave affected
- **W** – Wave dominated
- **Wf** – Wave dominated, fluvial influenced
- **Wt** – Wave dominated, tide influenced
- **Wft** – Wave dominated, fluvial influenced, tide affected
- **Wtf** – Wave dominated, tide influenced, fluvial affected
- **T** – Tide dominated
- **Tf** – Tide dominated, fluvial influenced
- **Tw** – Tide dominated, wave influenced
- **Tfw** – Tide dominated, fluvial influenced, wave affected
- **Twf** – Tide dominated, wave influenced, tide affected

**BOLD UPPER CASE** = Dominant process

**bold lower case** = Secondary process

**italic lower case** = Tertiary process

- **F, f, t** = Fluvial
- **W, w, w** = Wave
- **T, t, t** = Tidal

**• 15 Classification Categories**
Classification Categories

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- **T** – Tide dominated
- **Tf** – Tide dominated, fluvial influenced
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**Twf** – Tide dominated, wave influenced, tide affected

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• 15 Classification Categories
Updated Marginal Marine Classification

**Classification Categories**

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- **T** – Tide dominated
- **Tf** – Tide dominated, fluvial influenced
- **Tw** – Tide dominated, wave influenced
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- **T, t, t** = Tidal

- 15 Classification Categories
New Classification Categories

<table>
<thead>
<tr>
<th>Fluvial influenced facies</th>
<th>Tidal facies</th>
<th>Wave facies</th>
<th>Non Elements</th>
<th>Elements</th>
<th>Elements Sets</th>
<th>Elements Complexes</th>
<th>Grain size</th>
<th>Fluvial influenced facies</th>
<th>Tidal facies</th>
<th>Wave facies</th>
<th>Non Elements</th>
<th>Elements</th>
<th>Elements Sets</th>
<th>Elements Complexes</th>
<th>Physical Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>e.g., Parasequence</td>
<td>Dimensions</td>
<td></td>
<td></td>
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</tbody>
</table>

**Elements**
- Thickness of sediment column

**Dimensions**
- Non Elements
- Grain size
- Elements
- Elements Sets
- Elements Complexes

**Non Elements**
- e.g., Parasequence

**Grain size**
- Dimensions
- Non Elements
- Elements
- Elements Sets
- Elements Complexes

**Fluvial influenced facies**
- Tidal facies
- Wave facies
- Non Elements
- Elements
- Elements Sets
- Elements Complexes

**Tidal facies**
- Wave facies
- Non Elements
- Elements
- Elements Sets
- Elements Complexes

**Wave facies**
- Non Elements
- Elements
- Elements Sets
- Elements Complexes

**Non Elements**
- e.g., Parasequence

**Elements**
- Thickness of sediment column

**Elements Sets**
- Tidal facies
- Wave facies
- Non Elements
- Elements
- Elements Sets
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**Elements Complexes**
- Tidal facies
- Wave facies
- Non Elements
- Elements
- Elements Sets
- Elements Complexes

**Physical Stratigraphy**
- e.g., Parasequence
- Dimensions
- Non Elements
- Grain size
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**Classification**
- Thickness of sediment column

**Physical Stratigraphy**
- e.g., Parasequence
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**Classification**
- Thickness of sediment column

**Physical Stratigraphy**
- e.g., Parasequence
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**Classification**
- Thickness of sediment column
Wave-dominated system (W) on causal diagram
Wave-dominated system (W) on causal diagram
Wave-dominated system (W) on causal diagram

Classification
- Category
- Element Complex
  - Strandplain
- Element Set
  - Beach Ridge Sets
- Element
  - Beach Ridge Elements
  - Swale Elements
  - Coastal swamp fill element
  - Distributary channel fill element
  - Abandoned channel fill element

Physical Stratigraphy
- e.g., Parasequence
- Elements
- Sets
- Complexes
- Dimensions
- Grain size
- Fluvial influenced facies
- Wave facies
- Tidal facies
- Thickness of sediment column
Wave-dominated system (W) on causal diagram
Wave-dominated system (W) on causal diagram

Processes and Basin Variables

- Sediment Supply
- Avulsion Frequency
  - Source lithology
  - Drainage Area
  - Subsidence/uptilt
  - A/S
  - Climate
  - Precipitation
  - Wind velocity
  - Wave energy at shoreline
  - Wave energy at shoreline
  - Fetch
  - Local accommodation
  - Seabed friction
  - Tidal range at shoreline
  - Tidal range at shoreline
  - Tidal prism
  - Tidal prism
- Basin length
- Basin width
- Basin depth
- Presence of tidal wave
- Tidal resonance
- Amphidromic point
- Continent configuration
- Eustatic sea level
- Tectonic setting

Source: Lithology
Drainage area
Subsidence/uptilt
Precipitation
Wind velocity
Wave energy at shoreline
Local accommodation
Seabed friction
Tidal range at shoreline
Tidal prism
Wave-dominated system (W) on causal diagram
Wave-dominated system (W) on causal diagram
Sequence Stratigraphy

Processes and Basin Variables

Classification

Output Categories
- Systems Tracts
No paleogeography input leads to poor prediction capability for shoreline architecture
Galloway (1975)

Output Categories
- Fluvial-dominated delta
- Wave-dominated delta
- Tide-dominated delta
Boyd et al. (1992; 2006)

Processes and Basin Variables

Output Categories
- Delta
- Wave-dominated Estuary
- Tide-dominated Estuary
- Lagoon
- Strandplain
- Tidal flat
Processes and Basin Variables

Ainsworth et al. (2008; in review) Predictive Matrices

Outputs Ranges of Categories:
F, Fw, Ft, Fwt, Ftw, W, Wf, Wt, Wft, Wtf, T, Tf, Tw, Tfw, Tfw
Predictive Matrix as Decision Tree

Ainsworth et al. (in review)
Predictive Matrix as Decision Tree

1. Low tidal resonance
2. High wave effectiveness
3. Low A/S
4. Highly embayed shoreline

Predict Coastal Process Dominance

Tidal Resonance
Potential of Basin?

Low

Wave vs Fluvial
Effectiveness?

High Fluvial

High Wave

Low vs High A/S?

Low A/S

High A/S

Low A/S

High A/S

Shoreline
Morphology?

SL ME HE SL ME HE SL ME HE

Coastal Process
Dominance

Fw Ft Fw Ft Fw Ft Fw Ft

Fw Fw Fw Fw Fw Fw Fw Fw

Ftw Tfw Ftw Tfw Ftw Tfw Ftw Tfw

T T T T T T T T

Ainsworth et al. (in review)
Matrix Module in Wave Knowledgebase

Predictive Matrix

1. Do you think that the system was affected by low tidal resonance (e.g., narrow shelf) or high tidal resonance (e.g., wide shelf)?
   - low tidal resonance [✓]
   - high tidal resonance [ ]
   - I am not sure [ ]

2. Wave effectiveness relative to fluvial effectiveness
   - Low Wave Effectiveness and High Fluvial Effectiveness [ ]
   - High Wave Effectiveness and Low Fluvial Effectiveness [✓]
   - I am not sure [ ]

3. What is the Accommodation-over-Sediment supply ratio (A/S)?
   - low A/S [✓]
   - high A/S [ ]
   - I am not sure [ ]

4. Please choose the type of shoreline shape during progradation:
   - straight/lobate (SL) [ ]
   - moderately embayed (ME) [ ]
   - highly embayed (HE) [✓]
   - I am not sure [ ]
Matrix Module in Wave Knowledgebase

Predictive Matrix

1. Do you think that the system was affected by low tidal resonance (e.g. narrow shelf) or high tidal resonance (e.g., wide shelf)?

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   - highly embayed (HE)
   - I am not sure

Based on the information you provided, the following classification categories can apply to your system:

Categories: T:Tw:Twf:

Interactive form in database
An effective way of dealing with uncertainty

Ainsworth et al. (in review)
Predictive Matrix as Decision Tree

Predict Coastal Process Dominance

Tidal Resonance Potential of Basin?
- Low
- High

Wave vs Fluvial Effectiveness?
- High Fluvial
- High Wave

Low vs High A/S?
- Low A/S
- High A/S

Shoreline Morphology?

Coastal Process Dominance

An effective way of dealing with uncertainty

Ainsworth et al. (in review)
An effective way of dealing with uncertainty

Ainsworth et al. (in review)
Predictive Matrix

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   - highly embayed (HE)
   - I am not sure

Based on the information you provided, the following classification categories can apply to your system:

Categories: \( T_f; T_{fw}; T_w; T_{wf}; \)
Advantages of such an approach

- Extremely flexible and easily modifiable
- No limit to number of variables used as long as there is a practical need (3, 4, .... 8)
- It effectively links process/basin setting variables to physical stratigraphy but it does not mix the two
- Classification categories can be easily enhanced:

\[ W \]
Wave-dominated

\[ W_1 \]
Wave-dominated (low local accommodation)

\[ W_{1,FL} \]
Wave-dominated (low local accommodation; fine lower sand)
Conclusions

1) We introduce a new classification scheme, which deals effectively with mix influenced systems.

2) The classification does not mix processes with resultant stratigraphy.

3) The classification has been incorporated into the Wave Knowledgebase (a database under development), which allows:
   - predictive capabilities (process to classification)
   - linking geospatial data to classification
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