

**Presentations**

---

4-15-2011

## **Lecture 8: Muddy coasts**

Carl T. Friedrichs  
*Virginia Institute of Marine Science*

Follow this and additional works at: <https://scholarworks.wm.edu/presentations>



Part of the [Environmental Sciences Commons](#)

---

### **Recommended Citation**

Friedrichs, Carl T.. "Lecture 8: Muddy coasts". 4-15-2011. Environmental Hydraulics Masters Program, University of Granada, Granada, Spain.

This Presentation is brought to you for free and open access by W&M ScholarWorks. It has been accepted for inclusion in Presentations by an authorized administrator of W&M ScholarWorks. For more information, please contact [scholarworks@wm.edu](mailto:scholarworks@wm.edu).

## Colin Woodroffe (2002) "Coasts: Form, Process and Evolution", Outline of Chapter 8:

<b>8 Muddy coasts</b>	<b>378</b>
8.1 Historical perspective	381
8.1.1 Stratigraphy	381
8.1.2 Process studies	383
8.2 Tidal flats	386
8.2.1 Sedimentary characteristics	388
8.2.2 Tidal flat morphology	391
8.2.3 Longer-term coastal plain development	396
8.2.4 Cheniers and chenier plains	397
8.3 Tidal inlets and tidal creeks	400
8.3.1 Tidal inlets	400
8.3.2 Tidal creeks and creek dynamics	403
8.4 Salt-marsh and mangrove shorelines	407
8.4.1 Salt-marsh and mangrove vegetation	408
8.4.2 Species distribution	411
8.4.3 Geomorphological settings	413
8.4.4 Geomorphologically defined habitats	416
8.5 Salt-marsh and mangrove morphodynamics	418
8.5.1 Landforms and sedimentation	420
8.5.2 Modelling marsh accretion	424
8.5.3 Muddy coast morphodynamics and sea-level change	430
8.6 Summary	432

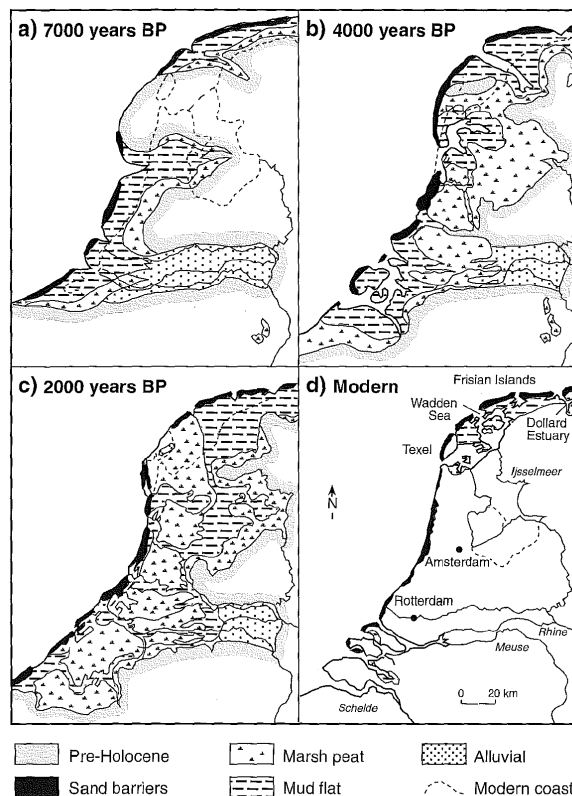


Figure 8.1. Holocene mudflat evolution on the Dutch coast (based on De Jong, 1977; Beets and van der Spek, 2000).

## 8. Muddy Coasts

- Low energy settings (BUT NOT ALWAYS!)
- And/or abundant supply of fine sediment
- Usually (but not always) dominated by tides
- Often fringed by marshes or mangroves
- Highly productive ecosystems
- Often associated with areas within estuaries, adjacent to deltas, behind barriers

### 8.1. Historical Perspective, 8.1.1. Stratigraphy

Mudge (1858) – Muddy marshes continually and gradually accrete vertically in response to sea level rise or subsidence.

Shaler (1896) – Muddy marshes expand horizontally across tidal flats.

Vaughan (1909) – Muddy mangroves expand horizontally across calcareous mudflats.

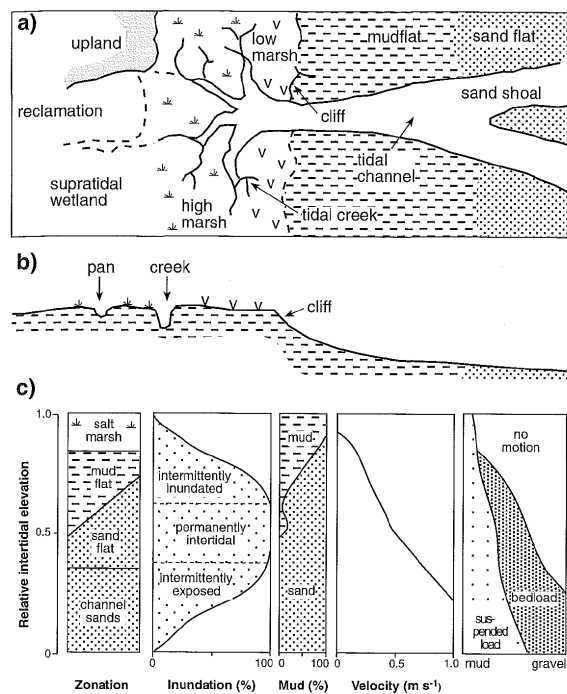
Egler (1952) – Mangroves can also accumulate vertical peat deposits, although less commonly. Perhaps calcareous mud doesn't compact as much?

### 8.1.2. Process Studies

O'Brien (1931) – Tidal inlet x-sectional area proportional to volume of tidal prism

Ecoffier (1940) – Concept of critical velocity maintaining equilibrium x-sectional area

Postma (1954) – Settling lag, scour lag moves mud landward

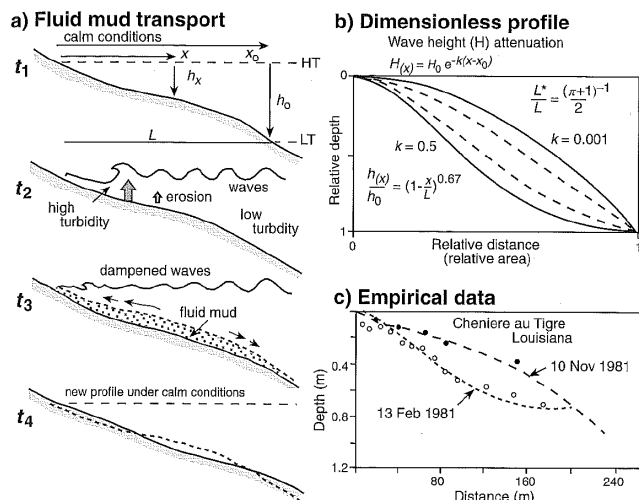


**Figure 8.2.** Variation of sedimentary characteristics across a typical muddy coast. (a) Schematic planform of muddy coast showing low-tide sand flat, intertidal mudflat and upper intertidal halophyte (salt-marsh or mangrove) area. (b) Schematic morphostratigraphic profile of mudflat. (c) Variation in sediment characteristics, inundation, mud content, peak tidal velocity and behaviour of sediment of different size fractions (based on data from the Wash and Bay of Fundy after Amos, 1995).

### 8.2. Tidal Flats; 8.2.1. Sediment Characteristics

L8/4

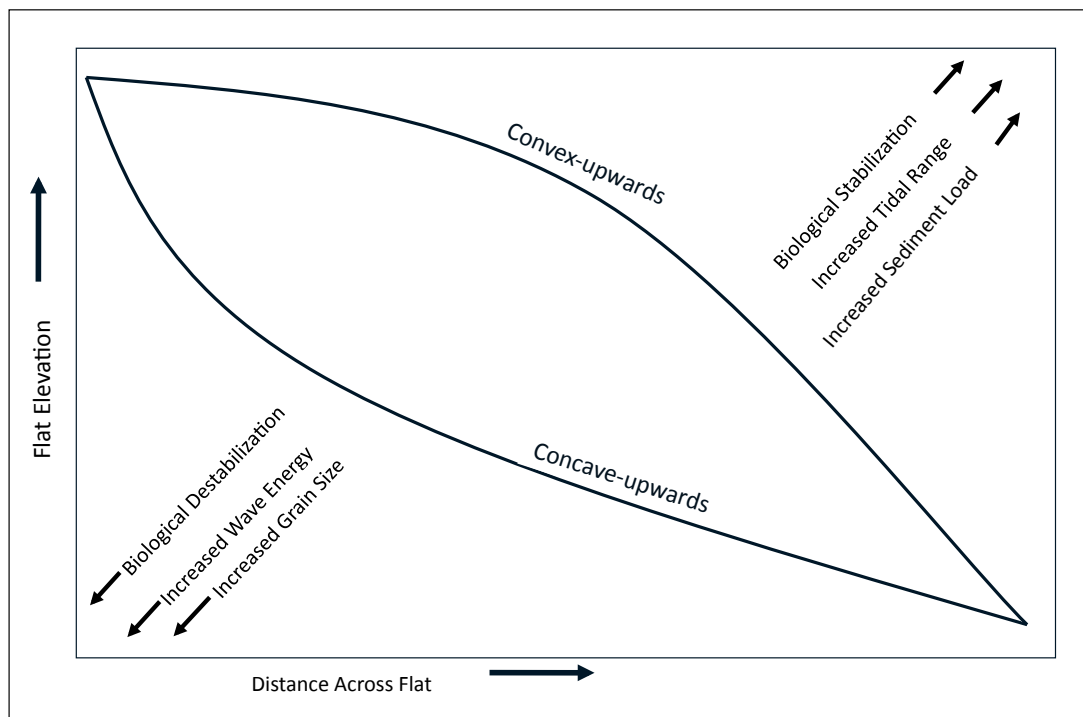
- Broad definition: flat and regularly flooded from sea without extensive (non-algae) vegetation.
- Most often classified based on elevation and sediment type.
- Supratidal, tidal, subtidal.
- Sandflats, mudflats, calcareous flats.
- Can be mostly sandy or mostly muddy, depending on sediment supply vs. energy.
- Lower flat is typically sandier, upper flat muddier, fringing marsh/mangroves muddiest.
- Tidal energy typically decreases toward shore.
- Generally landward transport under tidal conditions.
- Occasional wave energy reverses energy gradient, transports sediment offshore and favors coarser shoreline.



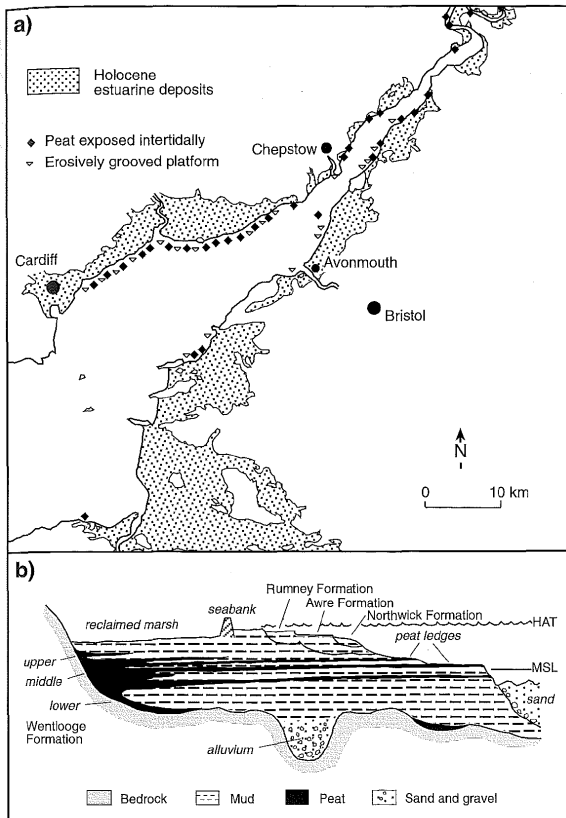
**Figure 8.3.** Mud behaviour and the evolution of mudflat shape. (a) Erosion and transport of fluid mud. Under calm conditions ( $t_1$ ), the bed is not agitated (parameters are defined). Under high wave energy maximum erosion occurs in the breaker zone ( $t_2$ ), and there is a gradient in turbidity. After a short time waves are dampened through attenuation in a fluid mud layer ( $t_3$ ), and net sediment is either moved shoreward by advection or offshore by gravitational movement. The new profile under subsequent calm conditions ( $t_4$ ) indicates the legacy of wave action on the profile. (b) Mudflat shape can be modelled under different conditions and degree of concavity relates to the wave attenuation coefficient ( $k$ ). The formulae express endpoints in the accretionary or erosional profile spectrum. (c) Data on offshore profiles in southwestern Louisiana indicate that observed depths (dots) correspond well with modelled (dashed) profiles for both erosional (February 1981) and accretionary (November 1981) profiles (based on Lee and Mehta, 1997).

### 8.2.2. Tidal Flats Morphology

- Flat shape tends to evolve toward zero energy gradient (uniform bottom stress).
- Uniform bottom stress under tides favors convex-upwards profile ( $t_1$ ).
- On convex profile, wave dissipation is concentrated on upper flat, transferring sediment seaward ( $t_2$ ).
- Fluid muds damp waves ( $t_3$ ).
- Uniform bottom stress under attenuating waves favors concave-upwards profile ( $t_4$ ).
- More wave attenuation favors convex profile (b).
- Erosion generally favors concave profile; accretion generally favors convex profile (c).



(Bearman, Friedrichs, Jaffe & Foxgrover, 2008)



### 8.2.3. Longer-Term Coastal Plain Development

- Peat layers indicate past periods of local regression of sea level.
- Mud over peat indicates a local transgression.
- Alternating layers indicate alternating regressions and transgressions.
- Peat is presently exposed in erosive, concave portions of modern tidal flat profile.

Figure 8.4. Severn River estuary and schematic stratigraphy. (a) Estuary showing alluvial areas that have accreted as Holocene coastal/estuarine plains, and (b) schematic cross-section showing morphostratigraphic units (based on Allen, 1992).

### 8.2.4. Cheniers and Chenier Plains

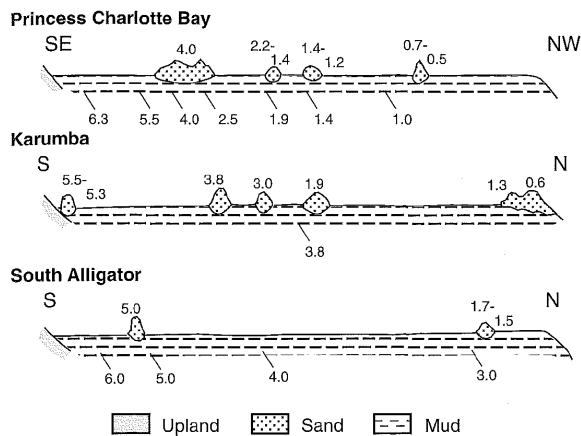
-- Chenier = coarse (sandy, gravelly, shelly) ridges perched above lower lying supra/intertidal muddy chenier plains. Named for live oak (*la chene*) found on Mississippi chenier ridges.

Figure 8.5. View across a northern Australian chenier plain, north of the Burdekin River, Queensland. The sandy ridges are perched on muddy sediments. The modern shoreline (foreground) is fringed with mangroves.

-- Found in accretionary, low tide range, high supply muddy (especially tropical) coasts.



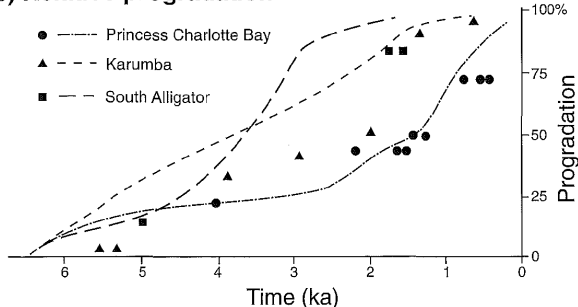
a) Schematic cross-section



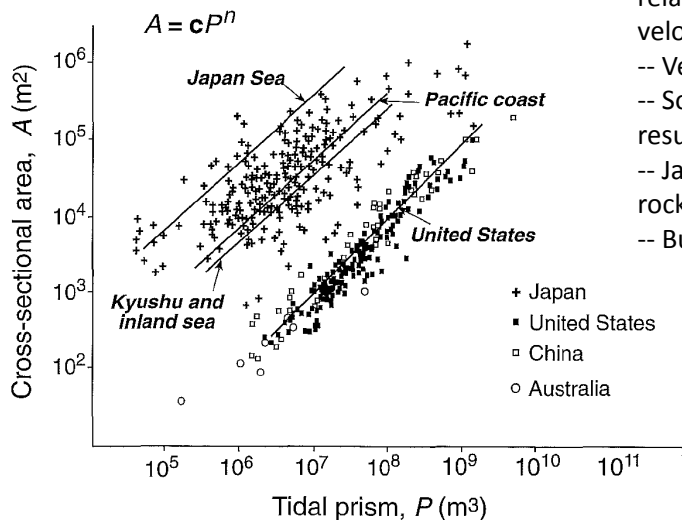
- Chenier ridge favored during erosive periods when coarse sediment is winnowed and along-shore transport is dominant.
- Extensive chenier ridge/plains form during periods of stable to falling sea level and shoreline progradation.
- Intermediate between tidal flat and beach ridge plain.

Figure 8.6. Stratigraphy and chronology of several chenier plains in northern Australia. (a) Schematic representation of the spacing and age (ka) of chenier ridges for parts of the Princess Charlotte Bay chenier plain (based on Chappell and Grindrod, 1984), a chenier plain at Karumba in the Gulf of Carpentaria (based on Rhodes, 1982), and a chenier plain at the mouth of the South Alligator River in the Northern Territory (based on Woodroffe *et al.*, 1989). (b) The relative timing of plain progradation and ridge formation, showing some disparity between chronology determined from shell ages (symbols), and that determined from the underlying stratigraphy (lines).

b) Relative progradation



8.3. Tidal Inlets and Creeks; 8.3.1. Tidal Inlets



- Tidal inlets are characterized by a relatively predictable maximum tidal velocity for stability.
- Velocity ~ (Tidal Prism)/(X-sect Area)
- So small range in peak tidal velocity results in Tidal Prism ~ X-sect Area
- Japanese inlets tend to be jettied or rocky
- But something is fishy here!

Figure 8.7. Relationship between cross-sectional area of tidal inlet (*A*) and tidal prism (*P*), showing data from Japan (Shigemura, 1980) and Australia (Williams, 1983) plotted against data for China and United States (based on Gao and Collins, 1994).

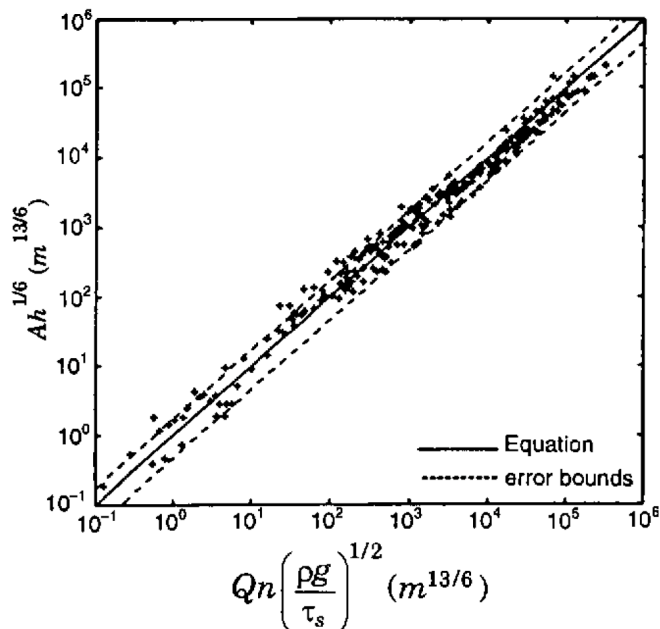


Figure 22. Observations of the cross-sectional parameter  $Ah^{1/6}$  for 236 sections from 25 natural marsh, estuary or tidal inlet systems (all sheltered from ocean waves) as a function of peak spring discharge, stability shear stress, and other externally fixed variables, superimposed on the 1:1 line given by the equation in the text. From Friedrichs (1995), published with permission of *Journal of Coastal Research*.

(from Friedrichs & Perry, 2001)

### 8.3.2. Tidal Creeks and Creek Dynamics

- Undermarsh (neap tides) vs. overmarsh (spring tides).
- Smallest tides are symmetric with currents decreasing at higher stages.
- Larger tides increase with stage with pulse around “bankfull” b/c of marsh inundation.
- Asymmetries occur with large tides and currents become ebb-dominant.

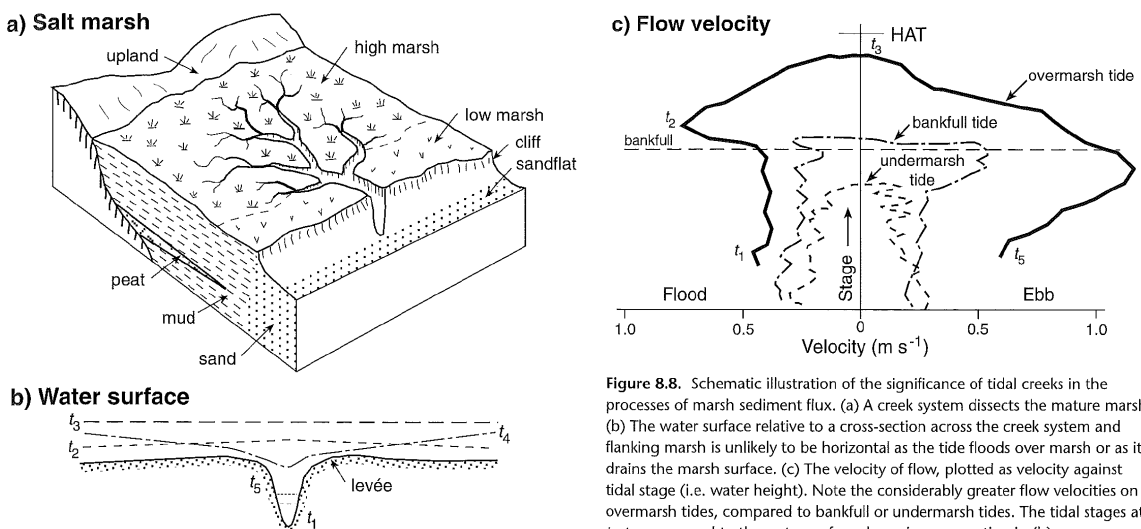


Figure 8.8. Schematic illustration of the significance of tidal creeks in the processes of marsh sediment flux. (a) A creek system dissects the mature marsh. (b) The water surface relative to a cross-section across the creek system and flanking marsh is unlikely to be horizontal as the tide floods over marsh or as it drains the marsh surface. (c) The velocity of flow, plotted as velocity against tidal stage (i.e. water height). Note the considerably greater flow velocities on overmarsh tides, compared to bankfull or undermarsh tides. The tidal stages at  $t_1$ - $t_5$  correspond to the water surface slopes in cross-section in (b).

- Major difference is marsh = grasses, mangrove = trees
- Vegetation in each case is stressed by salt and inundation

Figure 8.11. A prograding coast, van Diemen Gulf, northern Australia. The mangrove fringe is prominently zoned. It comprises a seaward zone of *Avicennia* and *Sonneratia*, then a zone of *Rhizophora*, then *Ceriops*, and a landward zone of stunted *Avicennia*. The plain behind the mangroves is supratidal and seasonally flooded.



Figure 8.10. The prop root systems of a stand of *Rhizophora stylosa* in northern Australia.



- Vegetation favors positive feedback and potential instability.
- More vegetation enhances deposition which enhances more vegetation and deposition.
- Less vegetation reduces deposition which stresses vegetation further.

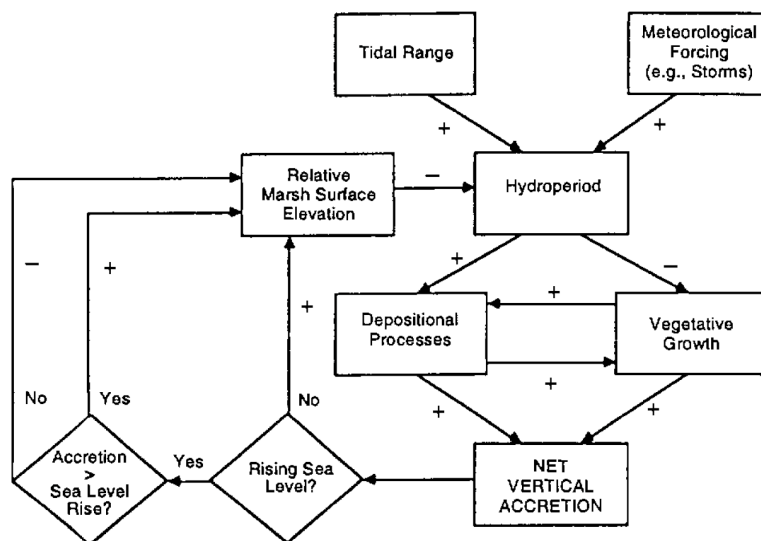


Figure 16. The interaction of tides, storms, hydroperiod, deposition, vegetative growth, sea level, marsh elevation and net vertical accretion. If the correlation between two components is positive, the arrow connecting the two boxes displays a "+", if the correlation is negative, the arrow displays a "-". From Reed (1990), published with permission of *Progress in Physical Geography*.

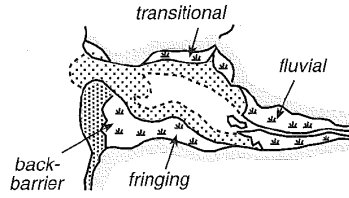
(from Friedrichs & Perry, 2001)



a) Deltaic

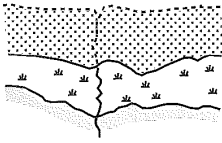


b) Estuarine

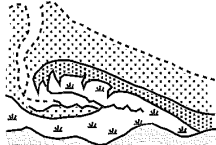


8.4.3. Geomorphological Setting

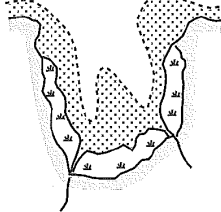
c) Open coast



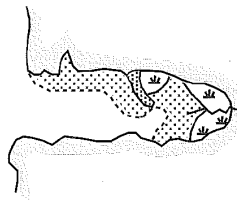
d) Back-barrier



e) Embayment



f) Drowned valley



-- Classification 1: Type of marsh/mangrove defined by the larger riverine/estuarine/coastal embayment setting.

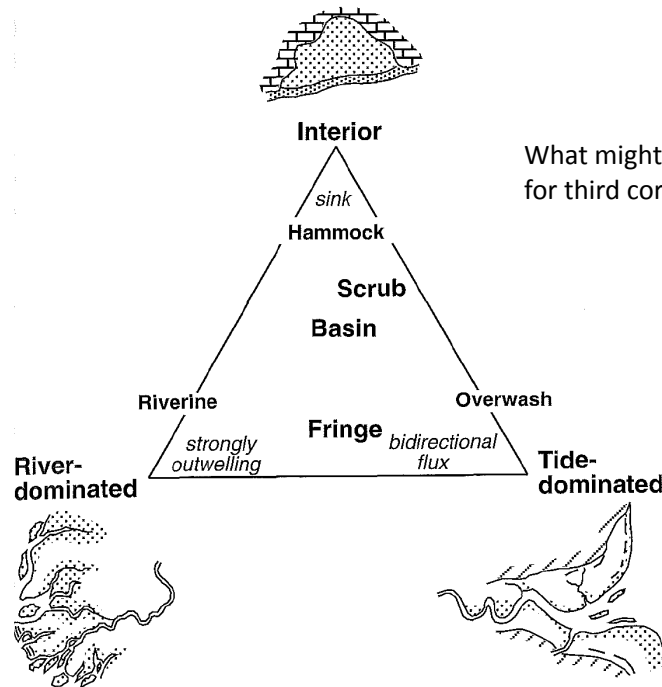
-- (a) Deltaic – fasted expanding and retreating with changing sediment supply, subject to rapid subsidence.

-- (b), (e), (f) – sheltered, slowly changing, stable (unless impacted by humans).

-- (c), (d) – occasionally subject to very large storms, episodically impacted.

— Upland    [dotted] Sand/mud flat    [dashed] Marsh    [stippled] Sand barrier

Figure 8.12. Geomorphological settings for salt-marsh and mangrove systems (based on Dijkema, 1987; Allen and Pye, 1992; French, 1997; Allen, 2000, and incorporating classes from Thom, 1982; Woodroffe, 1992). See text for details.



What might be other choices for third corner?

Figure 8.14. Continuum of processes affecting mangrove shorelines and settings within which mangroves are found, and representation of mangrove habitats in terms of the relative dominance of river, tidal or interior processes. The functional, ecological classification of Lugo and Snedaker (1974) is shown in relation to these gradients. The extent to which there is pronounced outwelling is also shown (based on Woodroffe, 1992).

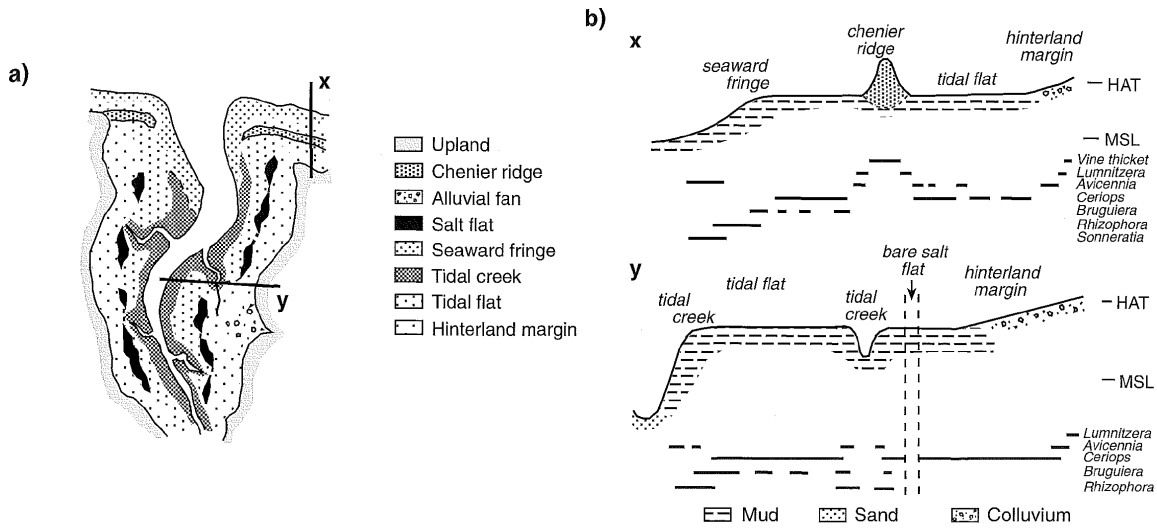


Figure 8.15. Mangrove environments in Darwin Harbour showing the division of geomorphologically based habitats within which mangrove associations can be recognised (habitat classification based on Semeniuk, 1985b; mapping based on Woodroffe *et al.*, 1988).

8.5. Salt-Marsh and Mangrove Morphodynamics

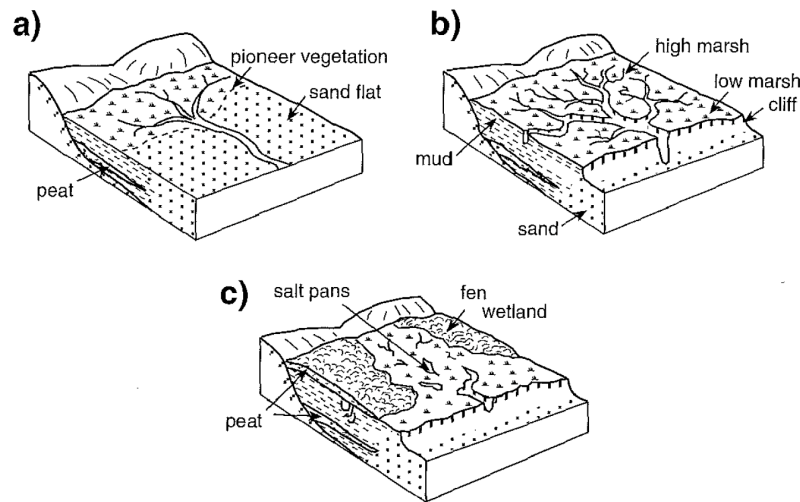


Figure 8.16. Schematic block diagram of (a) initial stages of salt-marsh formation; (b) mature salt marsh, and (c) salt marsh in which the upper surface has reached its maximum level and peat-forming non-halophytic environments are forming.

Evolution from “youthful” to “mature”. (Not really morphodynamics... Out of date!)

### 8.5.1. Landforms and Sedimentation

L8/19

- Levees – due to velocity slowing as water leaves channels.
- Slumps – due to undercutting, lateral spreading of marsh, returns sediment to channels.
- Salt Pans – positive feedback from hypersalinity kills vegetation which expands salt pans.

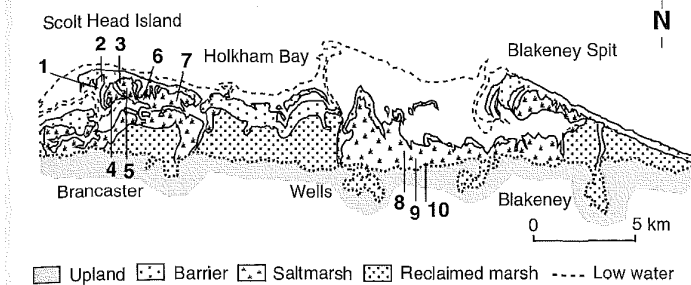


Figure 8.17. Cliff eroded into the seaward margin of salt marsh, Eskmeals, northwestern England.

Figure 8.18. Salt pan on the surface of high marsh, Eskmeals, northwestern England.



#### a) North Norfolk marshes



#### b) Marsh elevation

Marsh	Age (years)	Elevation (m O.D.)
1 Cockle Bight	-	1.79
2 North Cockle Bight	32±5	2.39
3 Spiral	93±9	3.01
4 Missel	57±20	2.57
5 Hut	93±10	2.73
6 Plover	>461±120	2.96
7 Great Aster	93±10	2.68
8 Wareham A	38±2	1.90
9 Wareham B	>2000	2.85
10 Wareham C	>2000	2.85

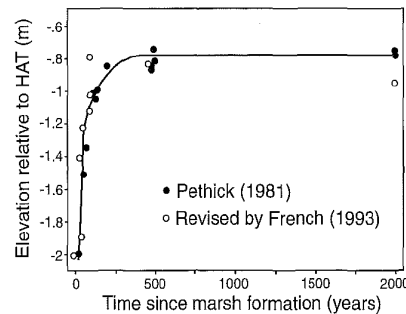
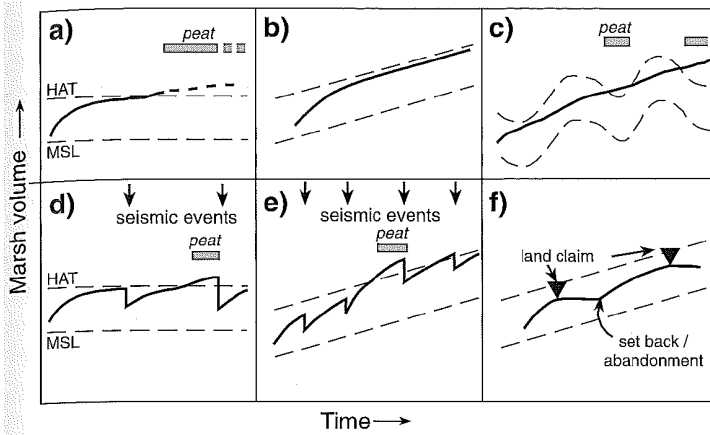


Figure 8.19. North Norfolk salt-marsh systems and the degree to which they have accreted and height of salt-marsh surface (based on Pethick, 1980; Stoddart *et al.*, 1989; French, 1993); (a) location of marshes, and (b) marsh age (relative to 1990) and elevation of highest vegetated surface (based on Pethick, 1981; French, 1993).

L8/20

- Submergence delivers sediment to marsh.
- Vegetation favors sedimentation by slowing water velocity.
- Sedimentation leads to accretion and reduces submergence time.
- Less submergence reduces sediment delivery to marsh.
- Sediment accretion can (increasingly slowly) approach high tide level but can never quite get there.
- With sufficient sediment, negative feedback allows long-term accretion rate to match rate of sea level rise.
- (Accretion above sea level by organic accumulation is possible, but then it isn't a tidal marsh anymore.)



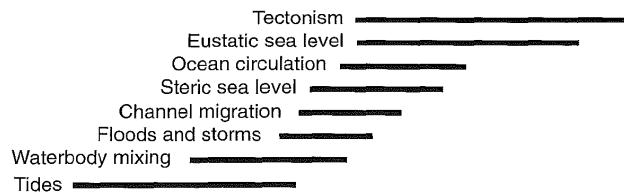
**Figure 8.20.** Schematic representation of the morphodynamics of salt marshes (based on Allen, 2000). (a) Steady state, sea level and other external boundary conditions held constant, the salt-marsh surface (volume) accretes asymptotically until organic accumulation takes it out of the tidal range (above HAT), after which peat accumulates. (b) Scenario in which sea level rises at a constant rate and marsh reaches maturity and then continues to accrete at a similar rate to sea-level rise. (c) Scenario in which sea level varies through time, rising irregularly. The marsh accretes but at times is above HAT; at these times peat accumulates. (d) Stable sea level, but episodic seismic subsidence rejuvenates marsh. (e) Episodic subsidence (seismic events) and rising sea level lead to complex salt-marsh morphodynamic response. (f) Situation where embankment and land claim lead to period of no change in embanked sedimentary volume (except subtle autocompaction) but, in face of sea-level rise, periodic set back or abandonment required.

### 8.5.2. Modelling Marsh Accretion

- Accumulation of sediment occurs if marsh is below Highest Astronomical Tide (HAT).
- Rate of sediment accumulation decreases exponentially as marsh elevation approached HAT.
- Organic (only) marsh accretion is possible above HAT, but this results in non-tidal, fully organic peat rather than sediment-rich tidal marsh deposit.
- Total marsh volume can only increase with sea level rise if marshes are allowed to expand inland.

**Figure 8.22.** Time scales over which (a) physical factors and (b) biological processes operate on mangrove shorelines (based on Woodroffe, 1992).

#### a) Physical



#### b) Biological

