Coastal Dynamics 1 (CIE4305)

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Section of Hydraulic Engineering

Don't forget to get a clicker……(and please hand it in again after the lecture!)

1-C Getting acquainted

see Chapter 9

Accretion on both sides

2.

Large-scale coastal variation

Recommended reading: Davis (1994). The evolving coast. Quite some photos and sketches in this chapter are taken from that book...

Coastal Dynamics 1

Contents

2. Large-scale coastal variation

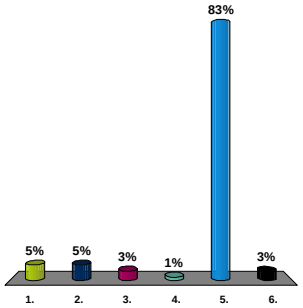
Contents

A. First order features
B. Geographical variation of coastal material
C. Tectonic plate setting
D. Effect of sea-level changes
E. Classification

Setting the scene …

Why would a Coastal Engineer bother about large scale coastal variation?

1. To enable first-order assessment of beaches worldwide
2. To distinguish short-term offsets from long-term trends
3. Because geological processes directly affect engineering design
4. To make an educated judgement on the threat of Sea Level Rise for Coastal Engineering
5. ✓ All of the above
6. Let's wait and see



2-A First order features

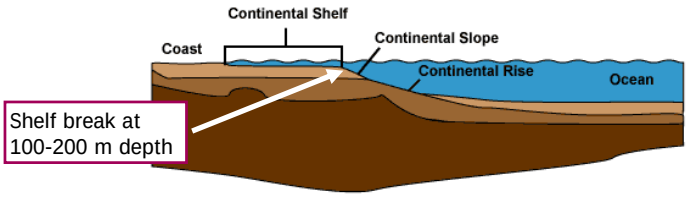
Length scales of coastal features

- First order features: thousands of kilometers
  - the broadest features of the coast
  - e.g. difference between Pacific and Atlantic coasts
- Second order features: tens to hundreds of kilometers
  - e.g. Outer Banks of North Carolina
- Third order features: a few kilometers
  - beaches, tidal inlets, individual barrier island

2-A First order features

First order features controlled by continental shelf width

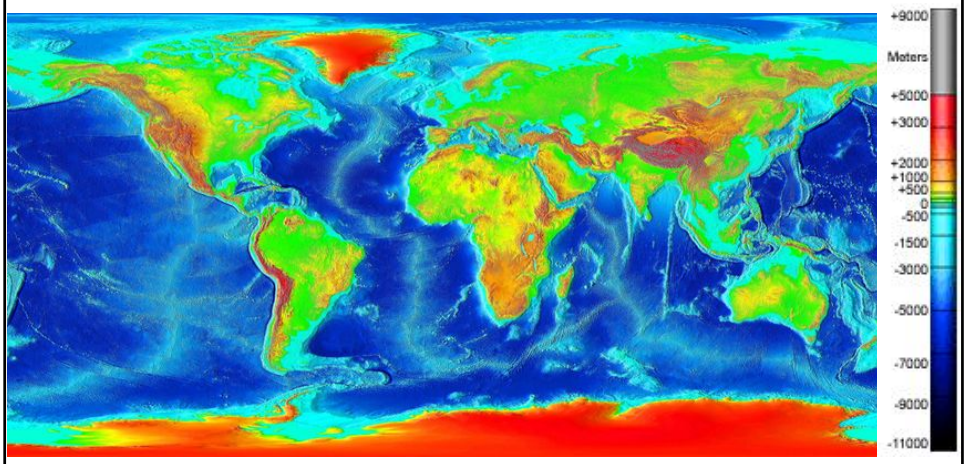
- Continental shelf:
  - flooded margins of the continents
  - covered by shallow seas



- Shelf width:
  - varying from tens of meters to 1500 km

2-A First order features

Shelf width



2-A First order features

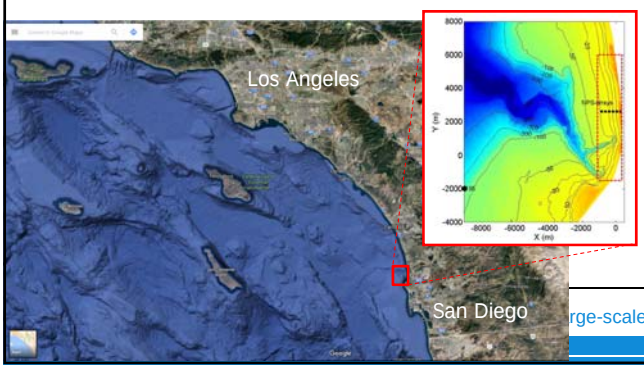
Wide and flat continental shelves

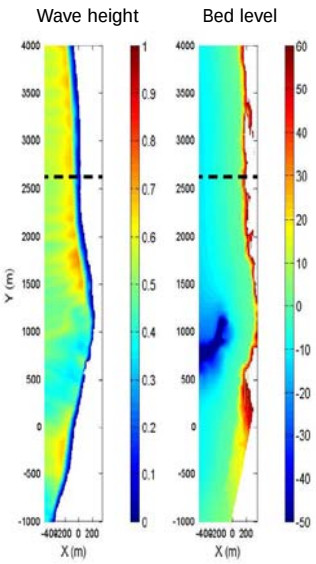
- Facilitate sediment accumulation
- Permit more rapid coastal progradation
- Reduce wave energy to a large extent
- Amplify tidal amplitude
- Have higher potential storm surge elevations

2-A First order features

Narrow and steep continental shelves

- Submarine canyon heads close to shore
- Energetic conditions
- Rapid dispersal of sediments
- Relatively little sediment on coast





After: Reniers (2005)

2. Large-scale coastal variation

Contents

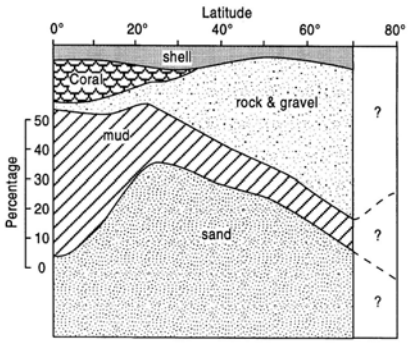
A. First order features
B. Geographical variation of coastal material
C. Tectonic plate setting
D. Effect of sea-level changes
E. Classification

2-B Geographical variation of coastal material

Coastal diversity: nature of material

- "Continental" sediments
  - Sand: lower middle latitudes
  - Mud: humid temperate or tropical hot climatic zones
  - Rock & gravel: high latitude and high relief coasts
- Coral
- Shell

Relative frequency of occurrence of inner continental shelf sediment types by latitude

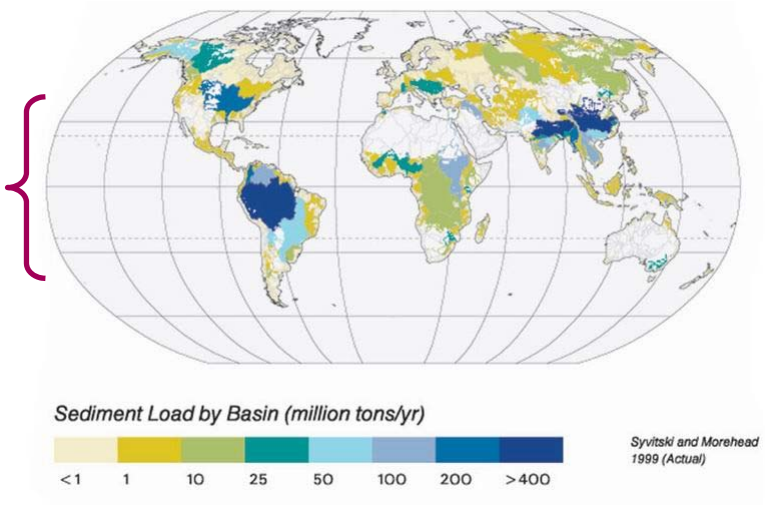


2-B Geographical variation of coastal material

The maximum extent of glacial ice in the north polar area during Pleistocene time

2-B Geographical variation of coastal material

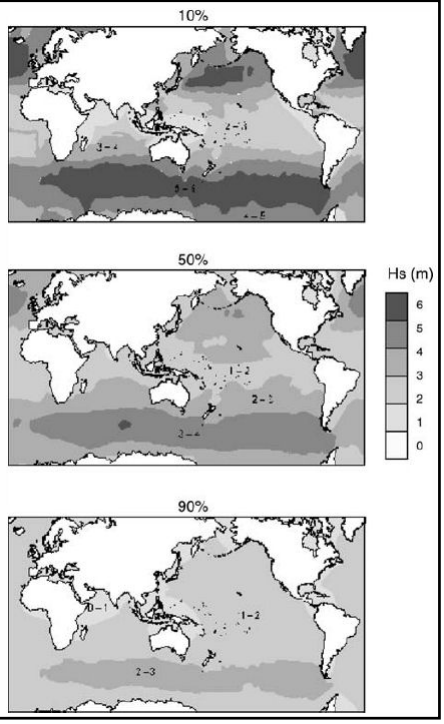
Supply of sand and fines to coast largest from 40°N to 40°S



2-B Geographical variation of coastal material

Higher mud content in tropics: chemical weathering and low energy

Global values for significant wave height which will be exceeded 10%, 50%, 90% of the time

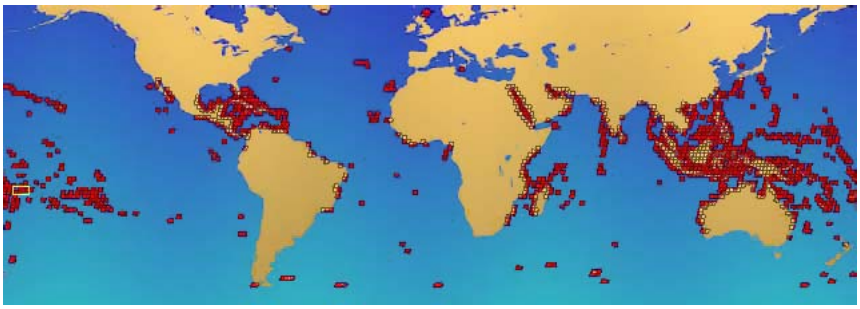


From Masselink and Hughes (2003)

2-B Geographical variation of coastal material

Global distribution of coral reefs

Fringing coral reef Eilat, Israel



2-B Geographical variation of coastal material

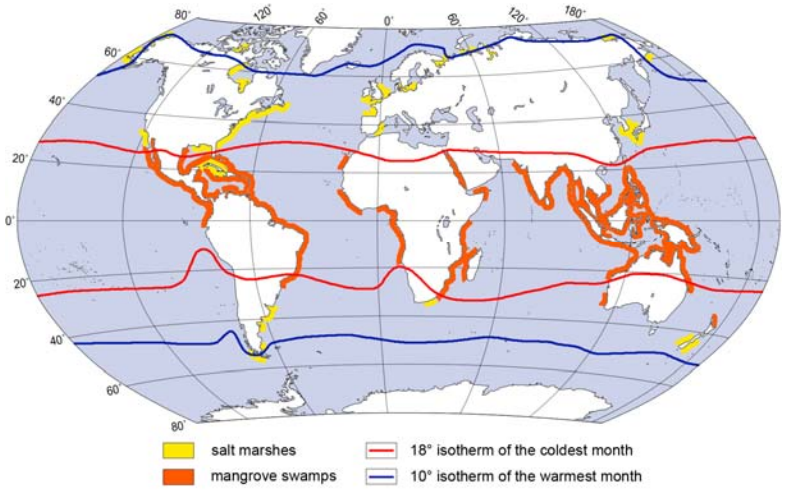
Biotic factors

- Coral reefs
- Mangrove swamps
- Salt marshes
- Dune vegetation

Mangroves

2-B Geographical variation of coastal material

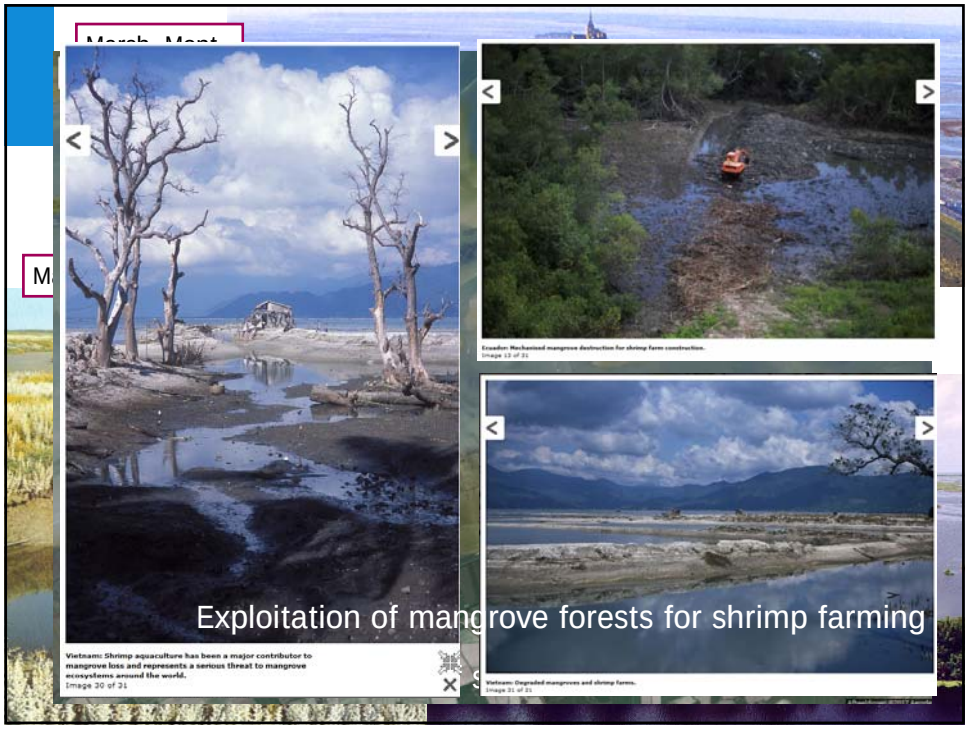
Salt marshes and mangrove swamps



2-B Geographical variation of coastal material

Marshes

Atlantic coastal salt marsh in Connecticut



2. Large-scale coastal variation

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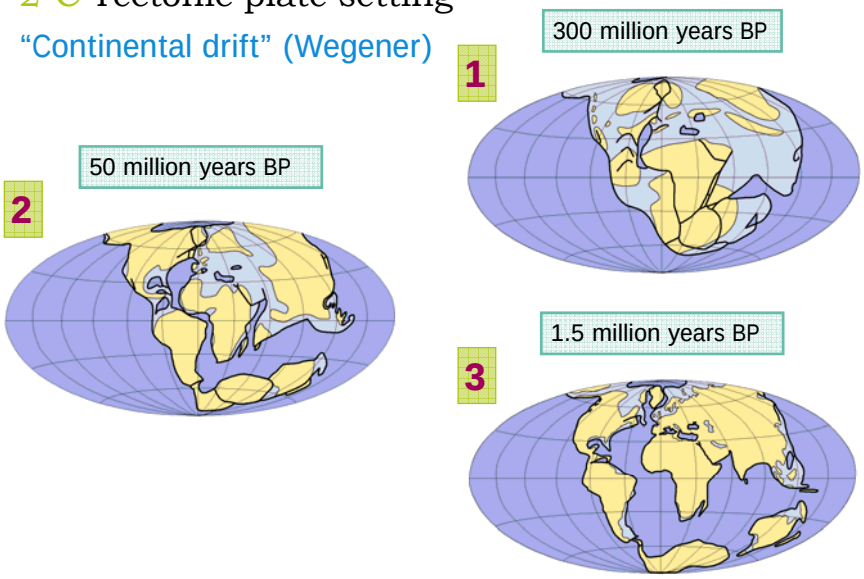
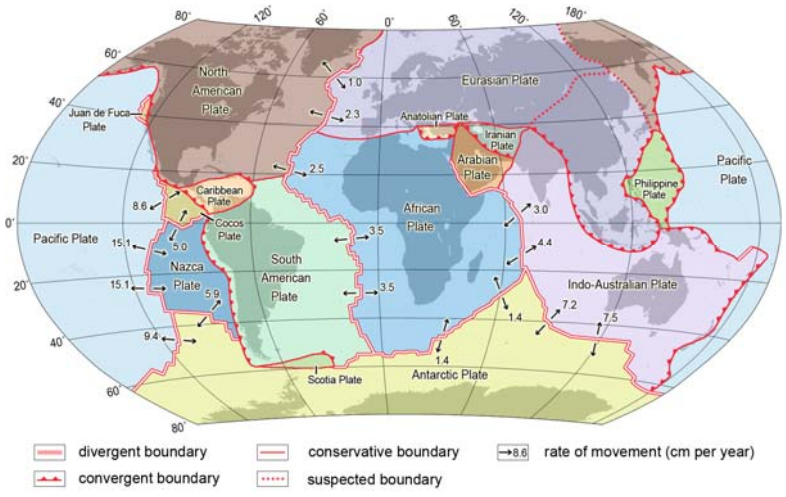
2-C Tectonic plate setting

"Continental drift" (Wegener)



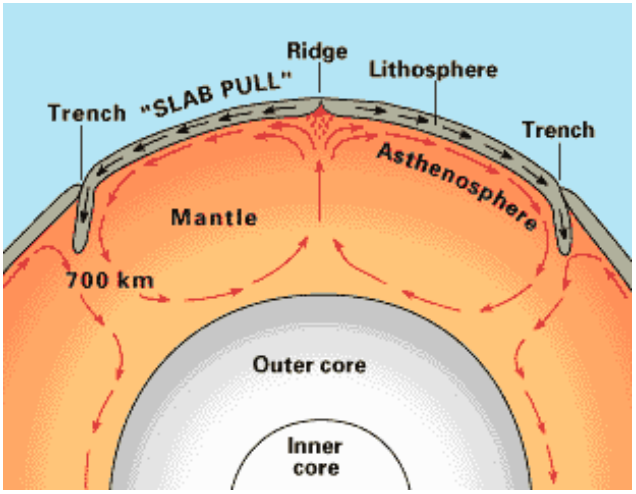
2-C Tectonic plate setting

12 major lithopheric plates in constant motion



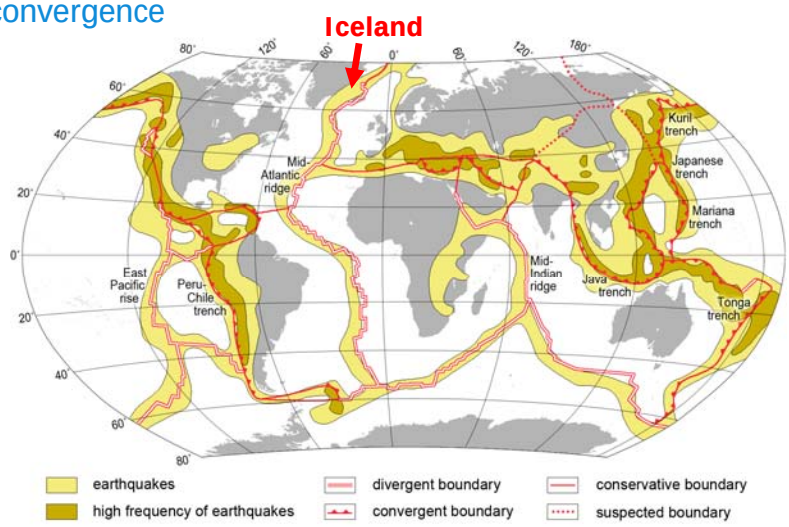
2-C Tectonic plate setting

Plate tectonic theory



2-C Tectonic plate setting

Ocean ridges coincide with spreading, trenches with convergence

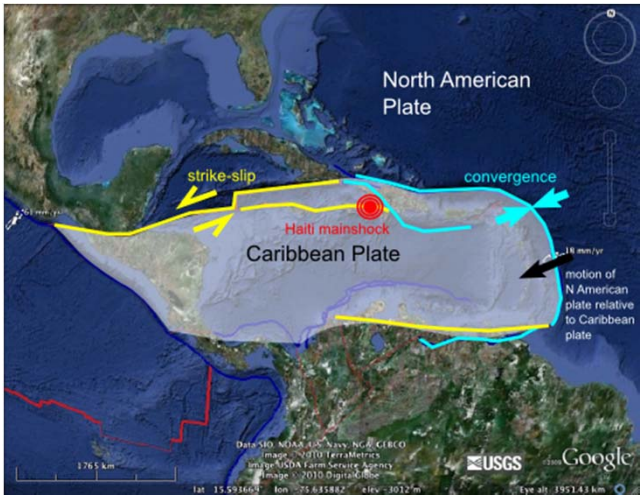


2-C Tectonic plate setting

Mid-Atlantic ridge at Thingvellir National Parc, Iceland

2-C Tectonic plate setting

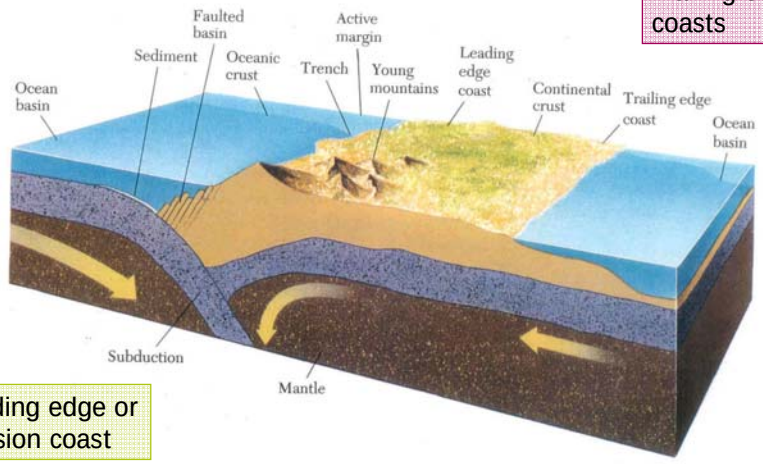
Haitian earthquake 13-1-2010



2-C Tectonic plate setting

Tectonic plate setting explains broadest coastal features

Trailing edge coasts

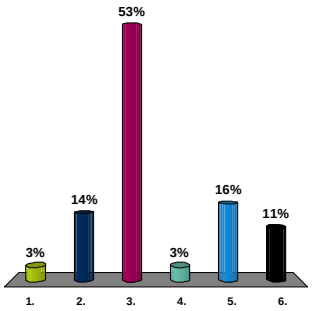


Leading edge or collision coast

2-C Tectonic plate setting

Characteristics of a leading edge coast are: (choose the statement that is **NOT** true)

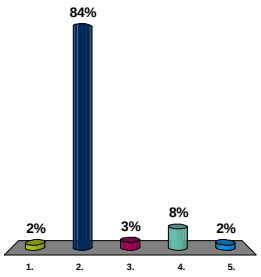
1. Steep coastal profile
2. Relatively coarse sediment supply from rivers
3. Limited wave action
4. Rugged, cliffed coastlines
5. Limited sediment deposition on the coast
6. I do not know



2-C Tectonic plate setting

Characteristics of a trailing edge coast are:
(choose the statement that is **NOT** true)

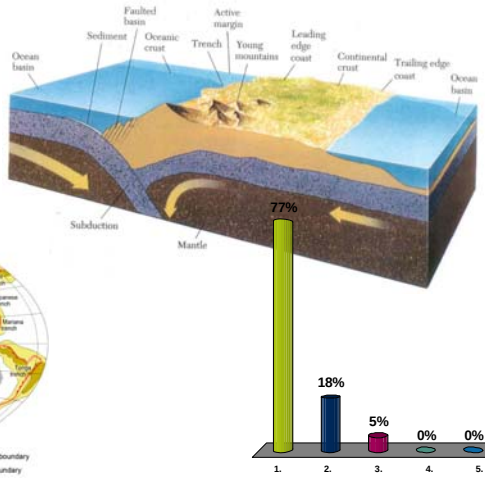
1. Tectonically stable
2. Rapidly flowing, short, steep and straight streams
3. Wide shelf with broad coastal plains, deltas and barriers
4. High potential storm surge elevations
5. I do not know

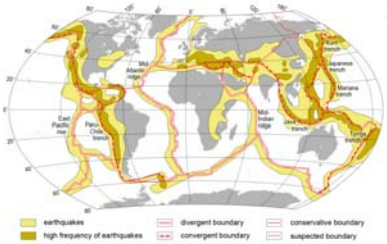


2-C Tectonic plate setting

Which continent are we looking at?

1. South America ✓
2. North America ✓
3. Africa
4. Australia
5. None of the above





2-C Tectonic plate setting

Characteristics leading edge coast (1)

- Rugged, cliffed coastlines
- Mountain ranges near the coast
- Volcanic ranges further from the coast (e.g. Andes)
- Tectonically unstable

Coast near Antofagasta, Chile

2-C Tectonic plate setting

Cape Kiwanda, Oregon

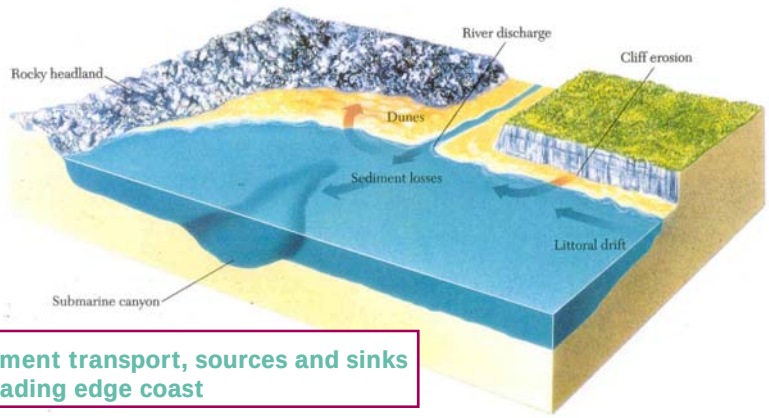
2-C Tectonic plate setting

Characteristics leading edge coast (2)

- Narrow continental shelf, steep coastal profile
- Large waves
- Rapidly flowing, short, steep and straight streams
- Relatively coarse sediment supply from river to coastal bays or open beaches

2-C Tectonic plate setting

Little sediment deposition on open beaches due to narrow shelf and wave action

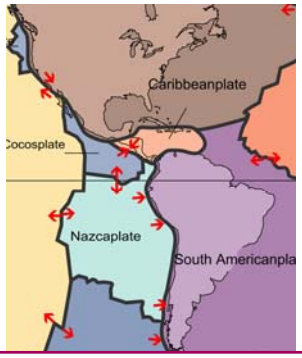


Sediment transport, sources and sinks at leading edge coast

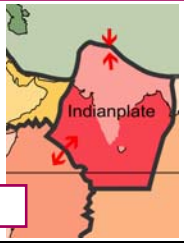
2-C Tectonic plate setting

Amero-trailing edge coast

- Far away from plate boundaries
- Tectonically stable (since continent separation)
- Wide shelf
  - limited wave action, larger tidal amplitudes & storm surge heights
- Large supply of sand and fines
  - (SA: from drainage divide on leading edge side of plate)
- Temperate climate
- Broad coastal plains, deltas and barriers



East coasts of N and S America



India

2-C Tectonic plate setting

Amero-trailing edge coast

- Tidal flats
- Mangrove

Coast near the Amazon River mouth, Brazil

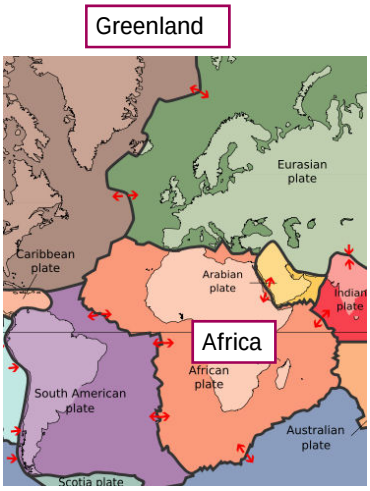
2-C Tectonic plate setting

Amero-trailing edge coast

2-C Tectonic plate setting

Afro-trailing coast: opposite coast also trailing

- Continent in middle of plate
- Little tectonic activity
- No high mountain ranges
- Pronounced shelves and plains
- Little river sediment supply (due to climate)
- Slow development of coast, no extensive deltas (except Niger Delta)



2-C Tectonic plate setting

Trailing edge coasts

- Plate-imbedded
- Large diversity:
  - neo-trailing edge coasts
  - afro-trailing edge coasts
  - amero-trailing edge coasts

Increasing maturity

- Most mature = most extensive sediment deposits and widest continental shelf

2-C Tectonic plate setting

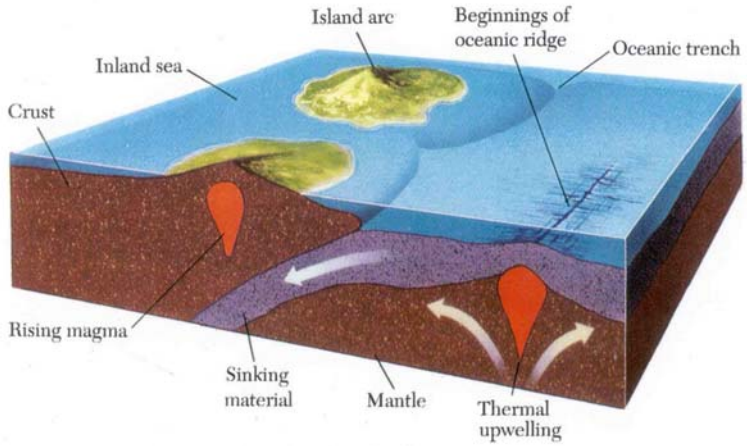
Tectonic classification of coasts (Inman and Nordstrom, 1971)

- Leading edge coasts or collision or convergent coasts: associated with the leading edge of a crustal plate
- Trailing edge or passive coasts: associated with the trailing edge of a plate (often mid-plate)
- Marginal sea coasts: bordering a sea enclosed between the landmass and a volcanic island arc at the plate boundary

Coastal character is influenced by proximity to and type of boundary

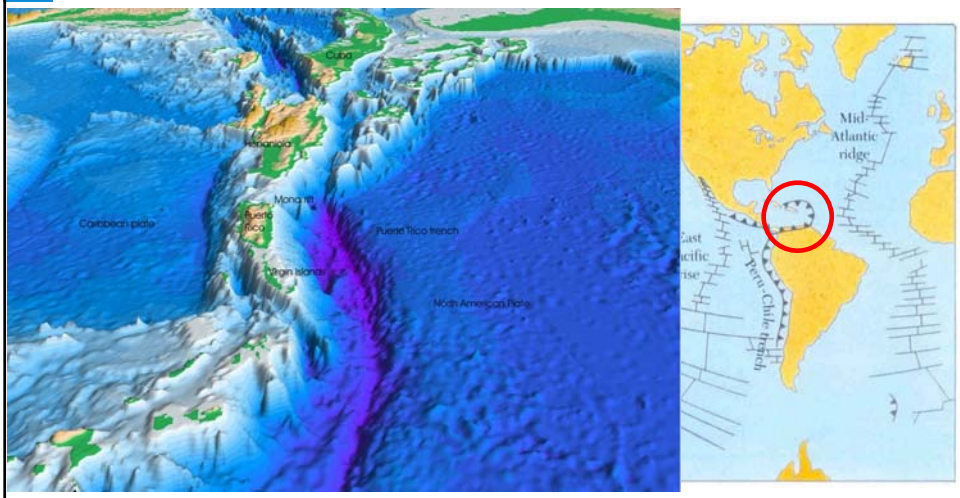
2-C Tectonic plate setting

Oceanic volcanic activity associated with convergence forms island arcs



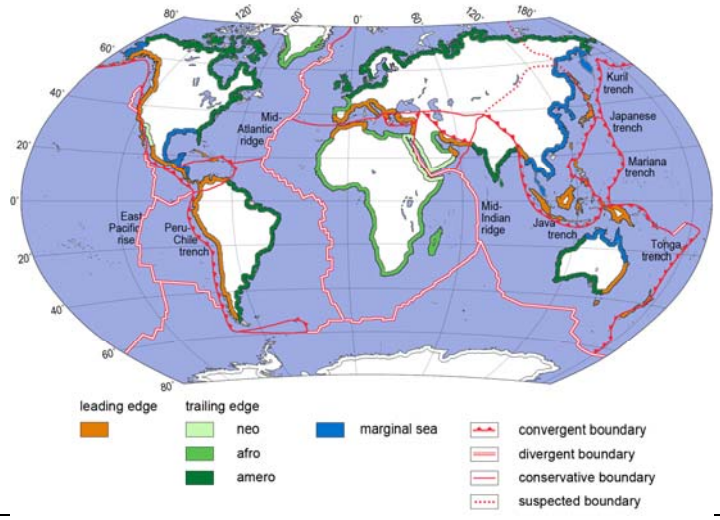
2-C Tectonic plate setting

Puerto Rico trench



2-C Tectonic plate setting

Tectonic-based classification of coasts

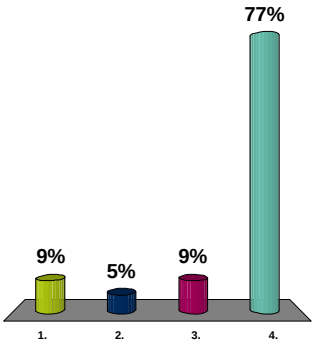


Question about Chapter 2

Where do **sandy** coastal systems (deltas, beaches, dunes, tidal sand deposits, barrier islands) dominate?

Which of the statements is wrong?

1. At passive coastal margins
2. In humid climates
3. ✓ In the tropics
4. In more energetic wave and tidal environments



Question about Chapter 2

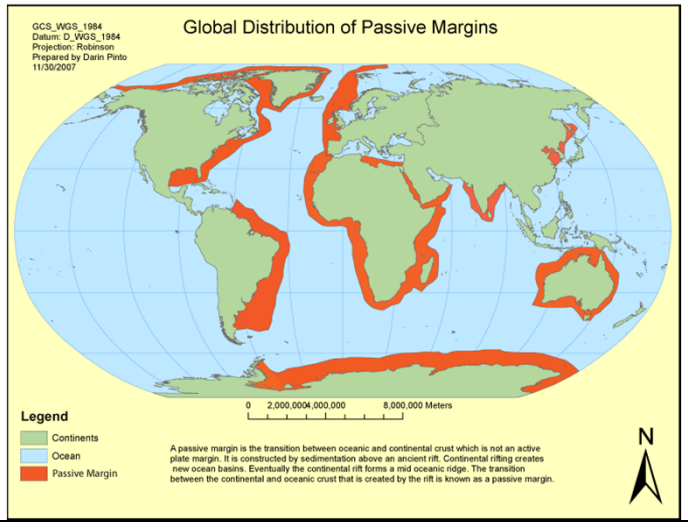
Sandy coasts dominate the subtropics and lower mid-latitudes (20˚-40˚)

- Humid climates
- Passive margin coasts
- Lower mid to low latitudes (in tropics mud dominates)
- More energetic wave and tidal environments

deltas, beaches, dunes, tidal sand deposits, barriers

From Chapter 3

Trailing edge or passive coasts



2. Large-scale coastal variation

Wrap-up Sections A-B-C

A. First order features
B. Geographical variation of coastal material
C. Tectonic plate setting
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2-C Tectonic plate setting

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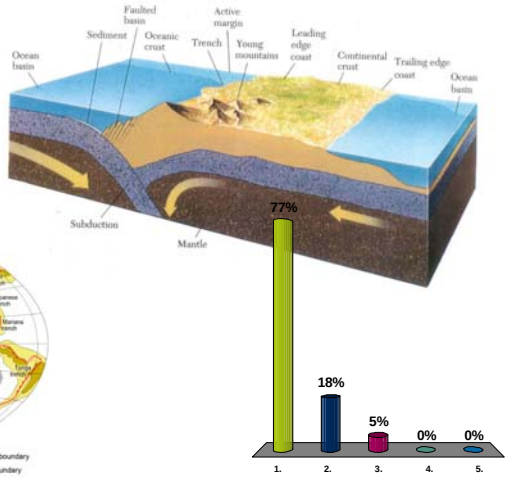
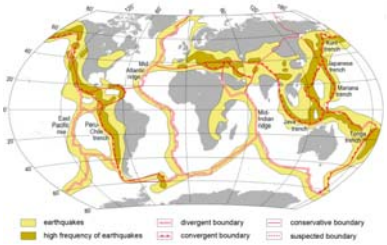
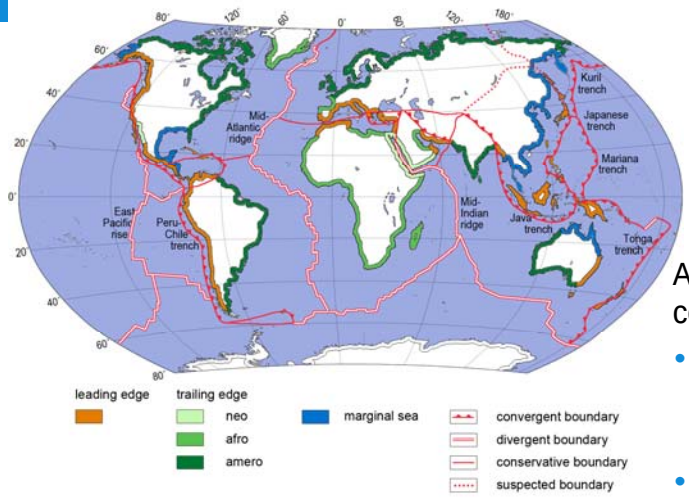




2-C Tectonic plate setting

Tectonic-based classification of coasts



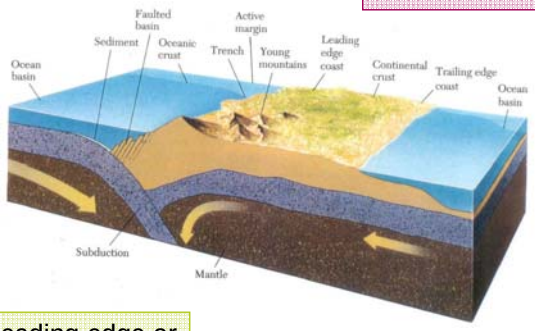
Appearance of coast -> Balance:

- Sediment supply from drainage basin
- Accommodation

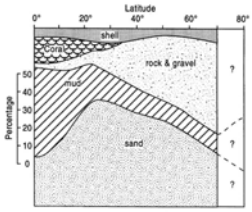
2-C Tectonic plate setting

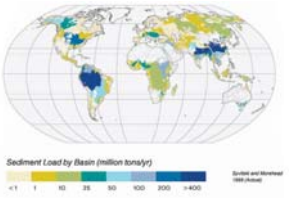
Tectonic-based classification of coasts

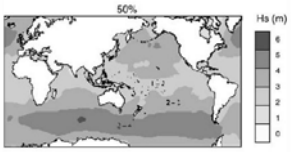
Trailing edge coasts



Leading edge or collision coast







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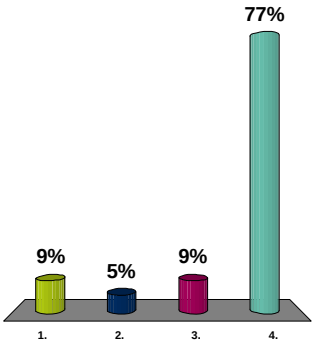

2. Large-scale coastal variation

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2-D Effect of sea level changes

Sea-level rise operates worldwide while helping to shape the coast at a regional level

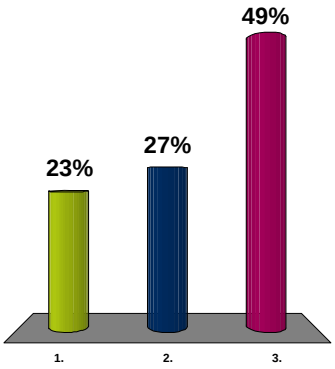
ria = drowned river valley

Georges River, Sydney

2-D Effect of sea level changes

Which of the following statements is **true?**

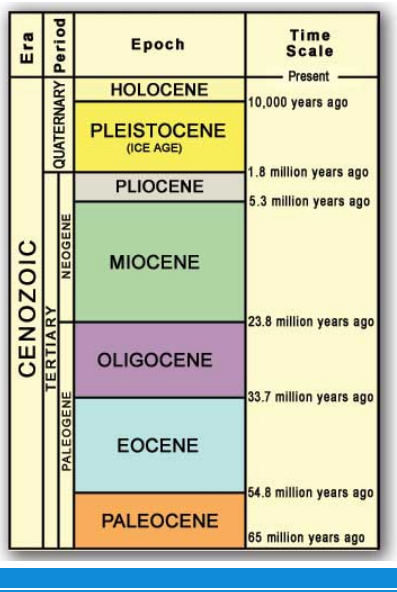
1. Georges River has a quite large sediment discharge
2. The order of magnitude of sea-level rise during the Holocene was 10 m
3. ✓ Rias can also be found along the South coast of England



2-D Effect of sea level changes

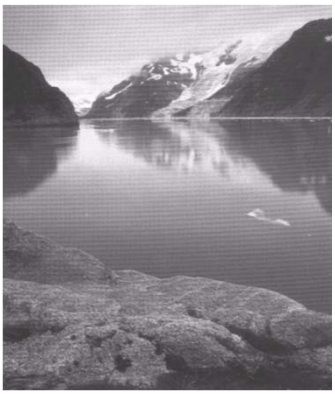
Quaternary climatic variations

- Holocene:
  - interglacial
  - sea level rise
- Pleistocene:
  - period of repeated glaciations
  - sea level fall during glacials
  - sea level rise during interglacials

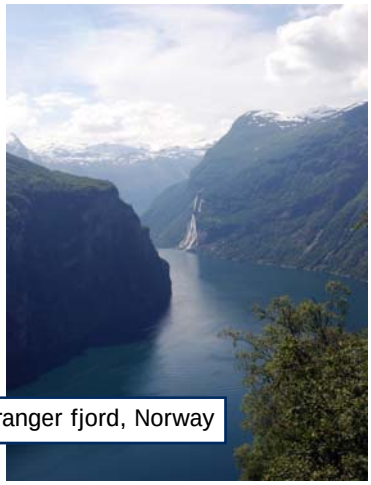


2-D Effect of sea level changes

Inheritance from ice ages: formation of fjords by glaciers



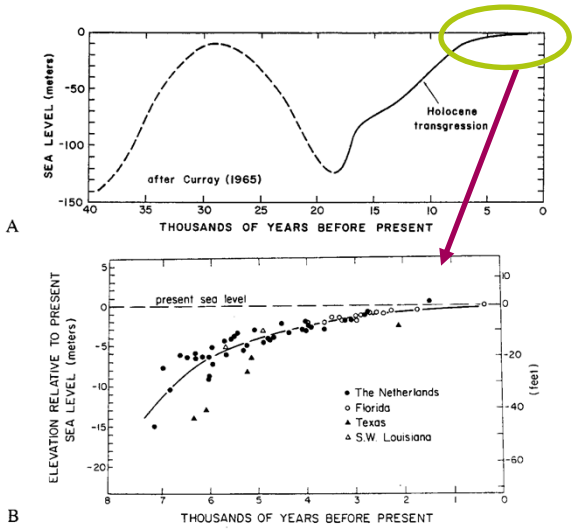
Kenai Fjords National Park, Alaska



Geiranger fjord, Norway

2-D Effect of sea level changes

Late Pleistocene and Holocene sea level variations



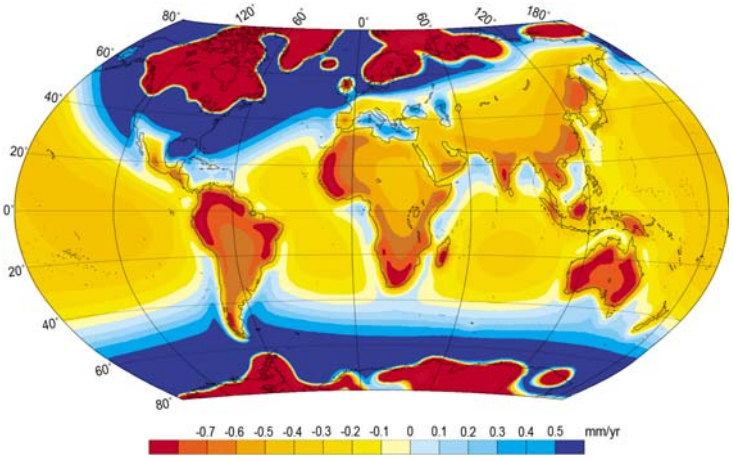
2-D Effect of sea level changes

"Global" and local effects

- Eustatic (absolute) or "global" changes
  - Changes in amount of water (advance and melting of ice)
  - Changes in expansion of water (due to temperature or salinity differences)
  - Changes in the volume of the ocean basins (plate tectonics, hydro-isostasy, marine sedimentation)
  - Changes in the shape of the oceanic geoid (e.g. due to melting of ice-sheet)
- Regional and local effects
  - Seismic activity
  - Isostatic effects:
    - Glacio-isostasy: loading and unloading by ice
    - Hydro-isostasy: loading and unloading by ocean water
  - Regional subsidence due to compaction and fluid withdrawal

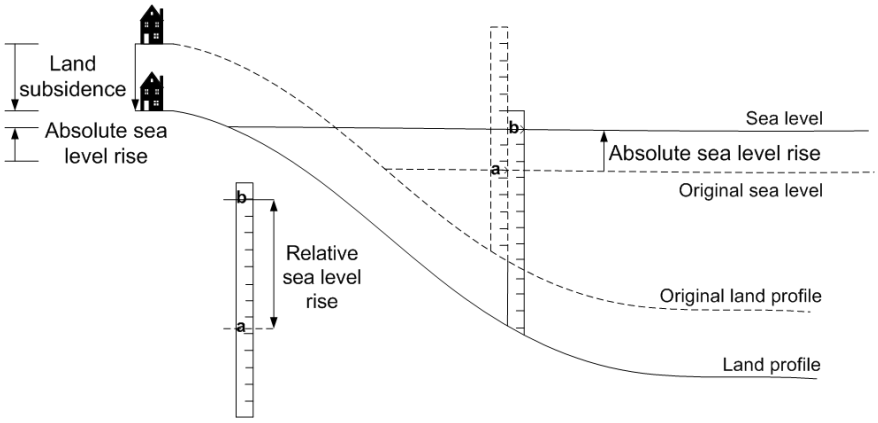
2-D Effect of sea level changes

Predictions of present-day rate of change of global sea level due to isostatic adjustments



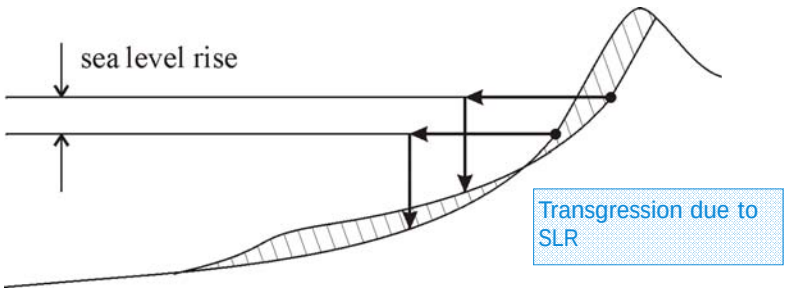
2-D Effect of sea level changes

Relative sea-level rise is the locally perceived sea level change



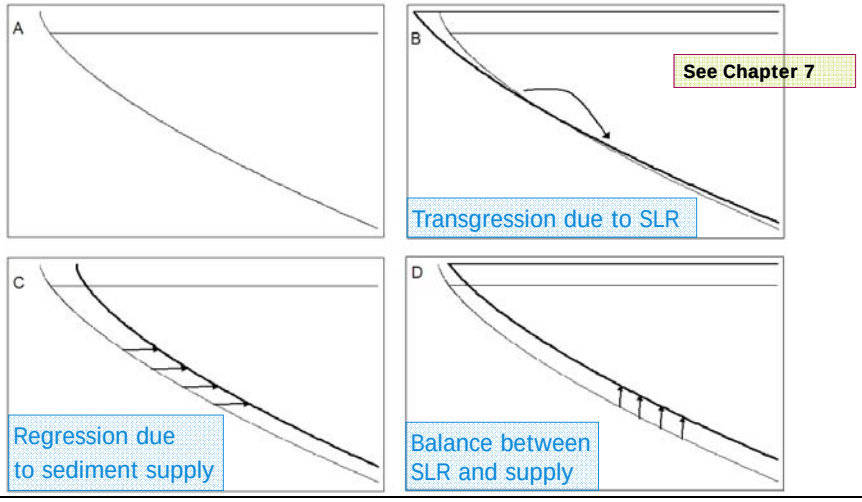
2-D Effect of sea level changes

Equilibrium shoreface response to sea-level rise: the Bruun rule



2-D Effect of sea level changes

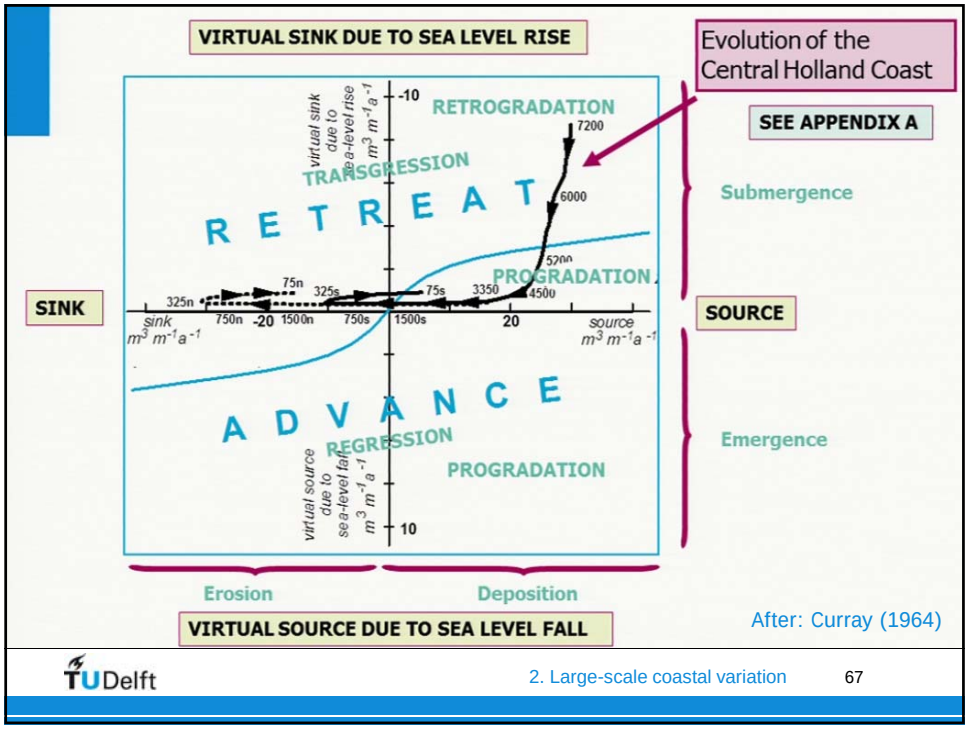
Equilibrium shoreface responses to sea-level rise in combination with sediment supply



2-D Effect of sea-level changes

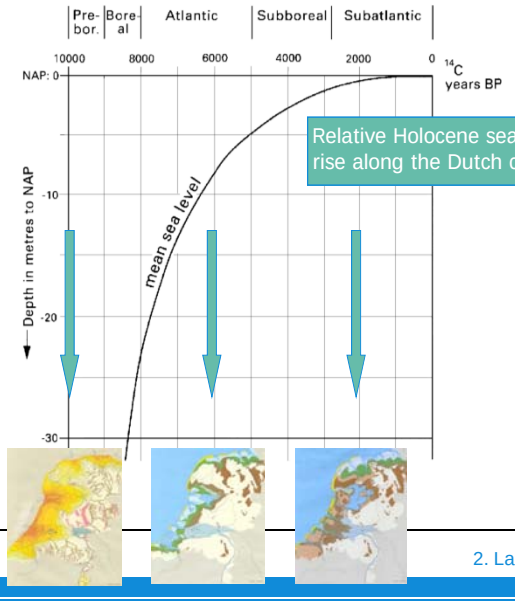
Balance between sea-level change and sediment supply determines retreat or advance of the coast

- Regression: seaward shift of the shoreline => former sea bottom exposed (water regresses)
- Transgression: landward shift of shoreline => flooding
- Progradation: sediment is deposited such that shoreline moves seaward
- Retrogradation: sediment is deposited but shoreline moves landward
- Emergence: land emerges out of the water due to relative sea-level fall (f.i. tectonic uplift, Chile)
- Submergence: inland regions are flooded due to relative sea-level rise



2-D Effect of sea level changes

Holocene development of the Dutch coast



Relative Holocene sea level rise along the Dutch coast

SEE APPENDIX A

- Alternate periods of retreat and advance governed by rate of relative sea-level rise and sediment sinks and sources
- Shaped by both terrestrial and “marine” deposits

2-D Effect of sea level changes

Classification of Valentin (1952)

- Coasts that have advanced (due to emergence and/or deposition)
- Coasts that have retreated (due to submergence and/or erosion)

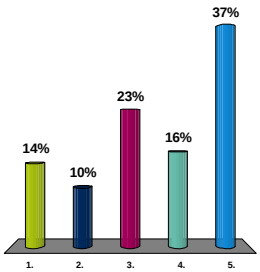
Classification of Shepard (1973)

- Primary coasts primarily shaped by non-marine agencies (ria's, fjords, delta)
- Secondary coasts primarily shaped by marine agencies (eroding cliffs, barriers, spits, coral coasts)

2-D Effect of sea-level changes

How would you characterize the Dutch coast?

1. A primary coast
2. A secondary coast
3. A coast that has advanced
4. A coast that has retreated
5. ✓ Depends



2-D Effect of sea-level changes

How to classify Dutch coast?

- Alternate periods of retreat and advance
- Shaped by both terrestrial and marine agencies

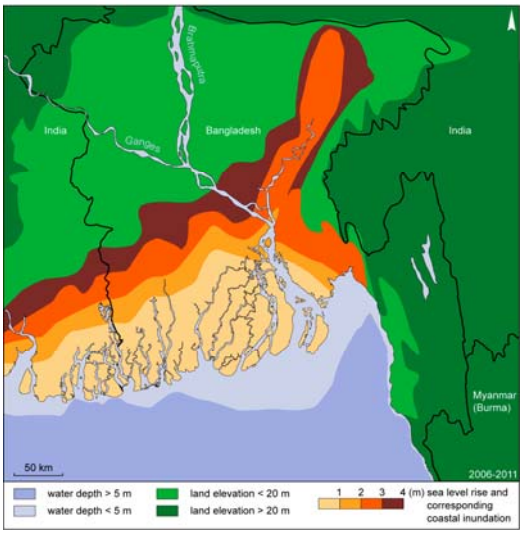
→ Classification implies an integration over a certain period

2-D Effect of sea level changes

Most vulnerable to sea level rise

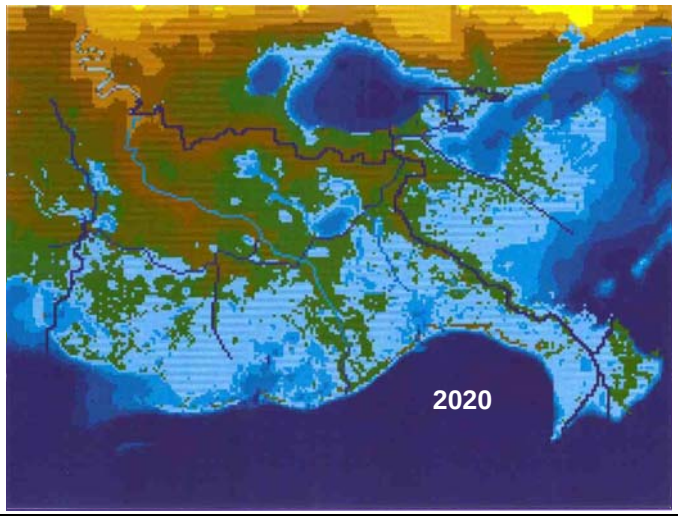
- Bangladesh
- Egypt
- Gambia
- Indonesia
- Maldives
- Mozambique
- Senegal
- Surinam
- Thailand

The latest projections of the IPCC (International Panel on Climate Change IPCC) indicate an SLR range from 0.18 m to 0.79 m by 2090-2099 relative to 1980-1999 (4th assessment report, 2007)



2-D Effect of sea level changes

Mississippi river delta



2. Large-scale coastal variation

Contents

A. First order features
B. Geographical variation of coastal material
C. Tectonic plate setting
D. Effect of sea-level changes
E. Classification

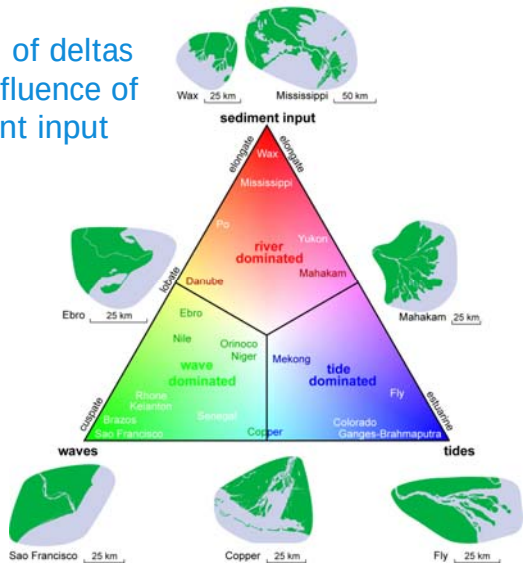
2-D Classification

Classification as a means to inventory the large variety of coastal systems

- Based on
  - Material – hard/soft, origin
  - Tectonic controls – e.g. Inman and Nordstrom (1971)
  - Sea-level criterion – e.g. Valentin (1952)
  - Based on dominant processes e.g. Shepard (1973)
- Scale dependent
  - Tectonic classification only broadest features / first order
  - Level of aggregation in process-based classification

2-D Classification

Galloway's classification of deltas based on the relative influence of waves, tide and sediment input

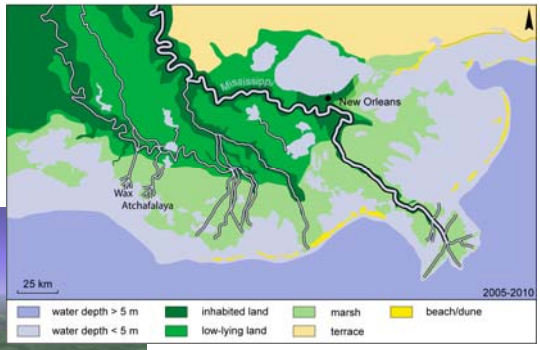


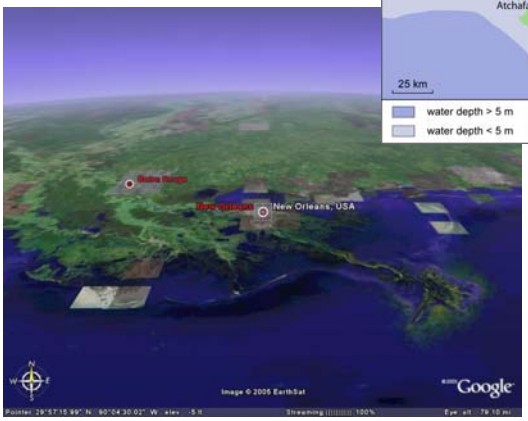
Exam question 2010:

In what geotectonic setting have deltas typically developed and why?

2-D Classification

River-dominated or bird foot delta



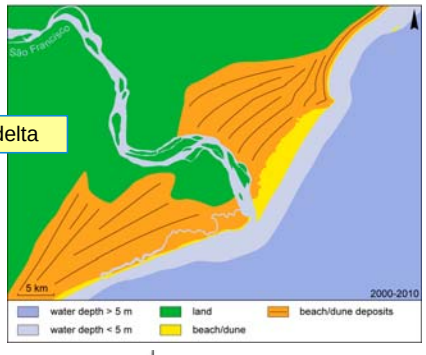


Mississippi river delta

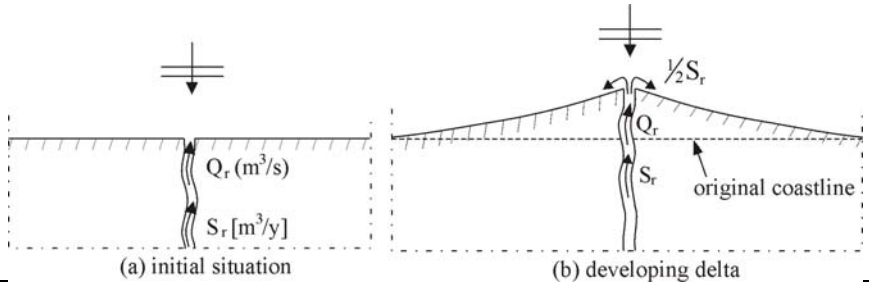
2-D Classification

Wave-dominated delta

Sao Francisco delta

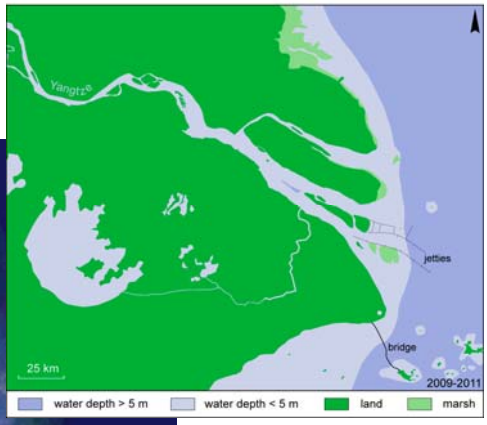


Normally incident waves



2-D Classification

Tide-dominated delta



Changjiang (Yangtze) river delta

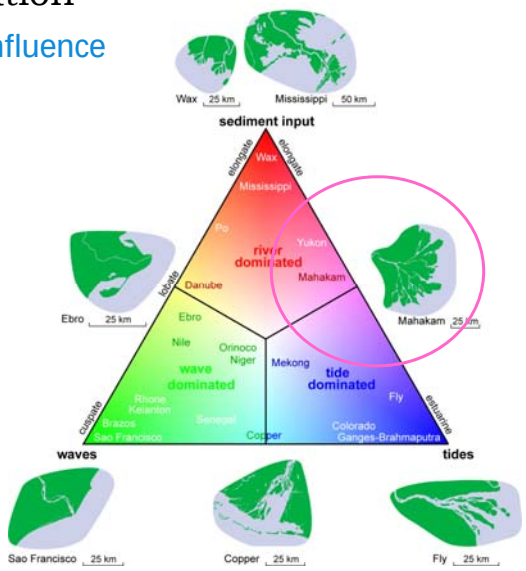
2-D Classification

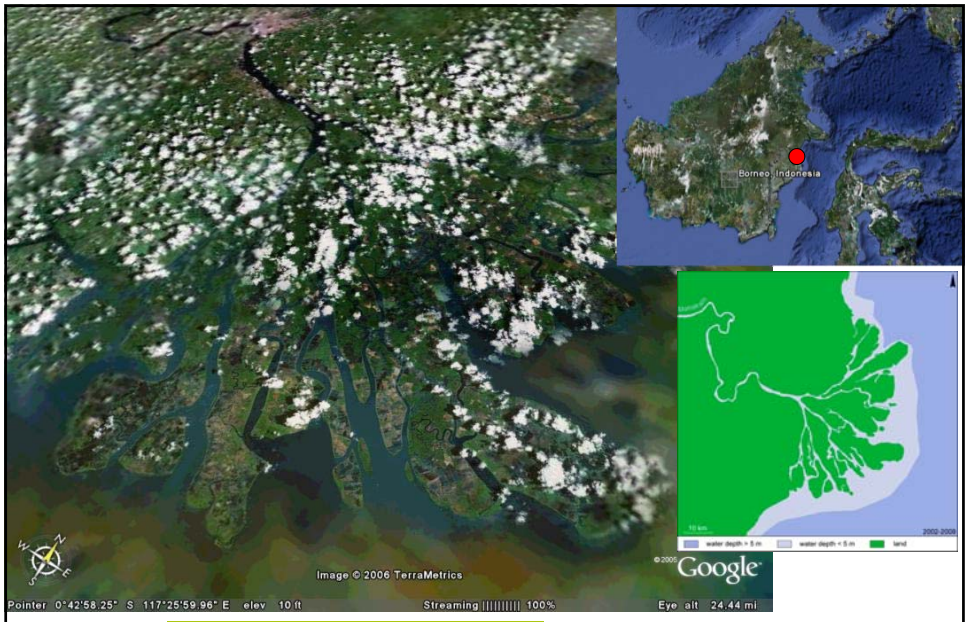
Tide-dominated delta (2)

Changjiang (Yangtze) river delta

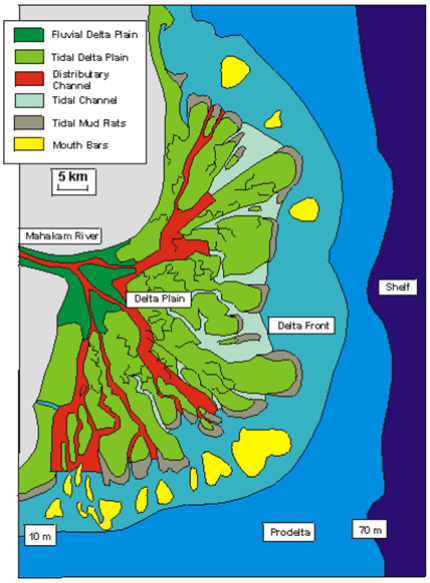
2-D Classification

Mixed river/tide influence





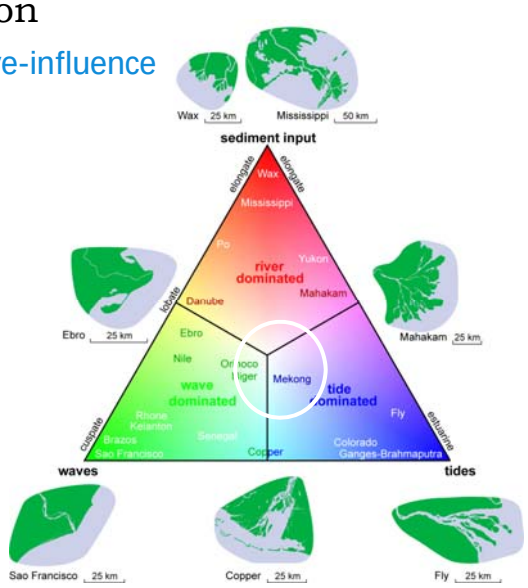
Mahakan delta, Kalimantan



http://fosi.iagi.or.id/mahakam/index.htm

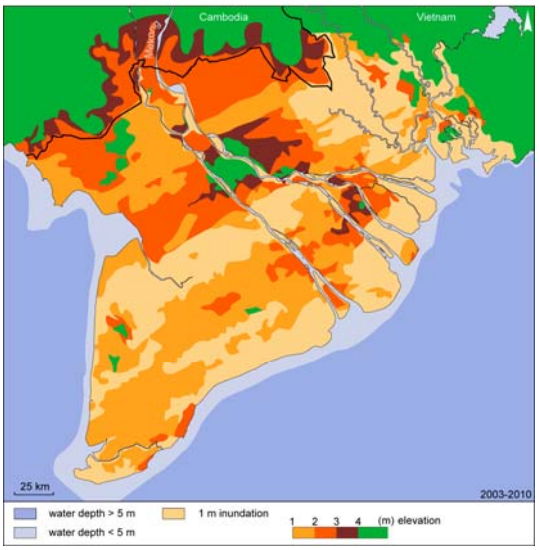
2-D Classification

Mixed river/tide/wave-influence



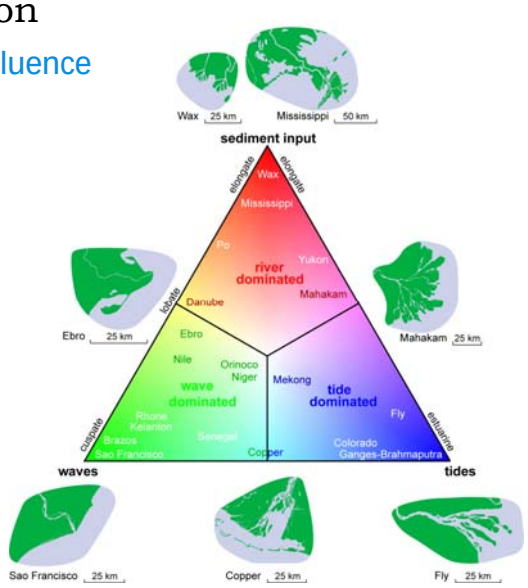
2-D Classification

Mekong Delta



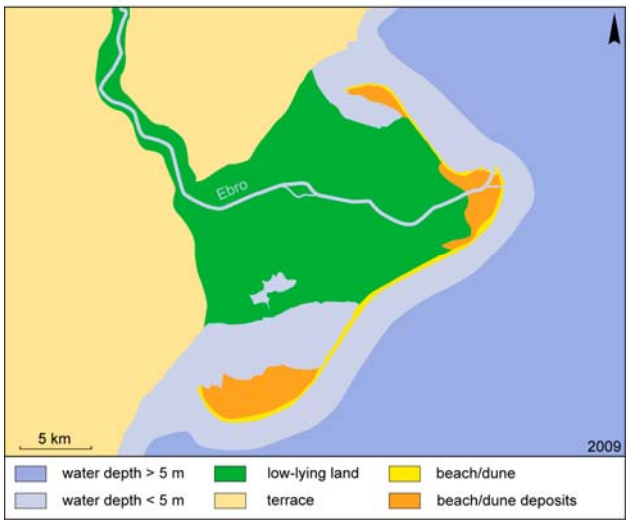
2-D Classification

Mixed river/wave-influence



2-D Classification

Ebro Delta



2-D Classification

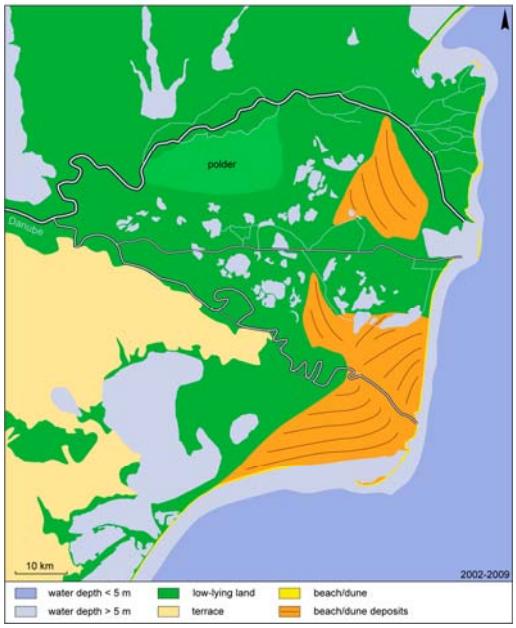
Danube Delta

Exam questions 2010:

This delta has originally developed as a river-dominated delta. How would you characterize the present-day Danube delta and why?

What is the dominant wave direction? Explain.

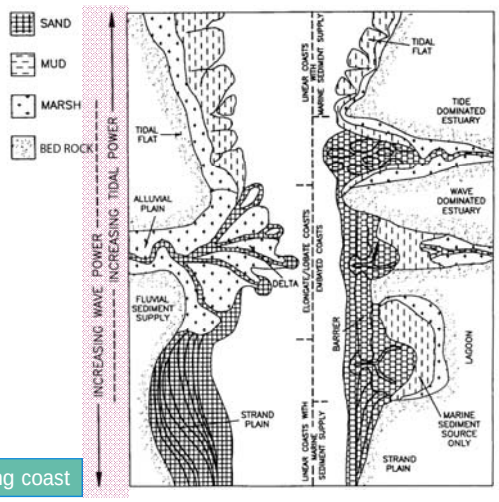
River/wave dominated



2-D Classification

Boyd (1992): relative influence of waves, tide and river

- Tidal flats
- Delta
- Strand plains



- Tidal flats
- Estuaries
- Lagoons
- Barrier

Compare Galloway's (1975) classification of deltas

Prograding coast

Transgressive coast

2-D Classification

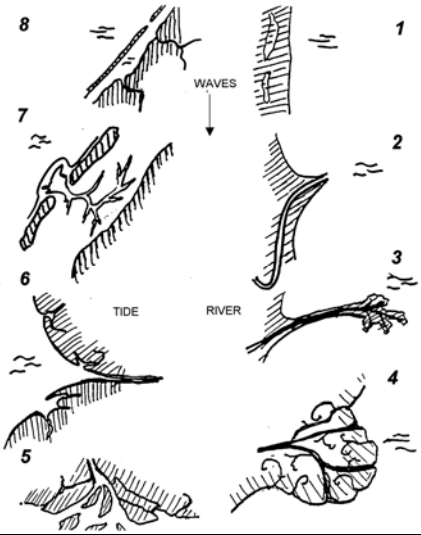
Relative influence of **waves**, **tide** and **river**

Wave-dominated barrier system

Tidal basins with **wave influence** at inlet

Tide-dominated estuary

Estuary. **River** deposits shaped by tide



Wave-dominated uninterrupted coastlines

Wave-dominated deltaic coastlines

Deltaic coastline. No waves or tides

Tide-dominated deltaic coastline

2-D Classification

Ternary shoreline classification diagram