Deep-Marine Clastic Systems

- **References:**
  - **Walker & James – Chapter 13**
  - **Emery & Myers – Chapter 9**

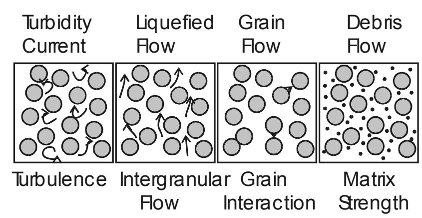
Deep-Marine Clastic Systems

- **Processes**
- **Submarine fans – facies models**
- **Controls on submarine fan development**
- **Summary**

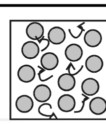
Processes

- **Submarine fan systems maintained by density currents**
- **Density currents transport clastic detritus (sand, gravel, mud) to deep water**
- **Four end-member types of density currents**

Processes

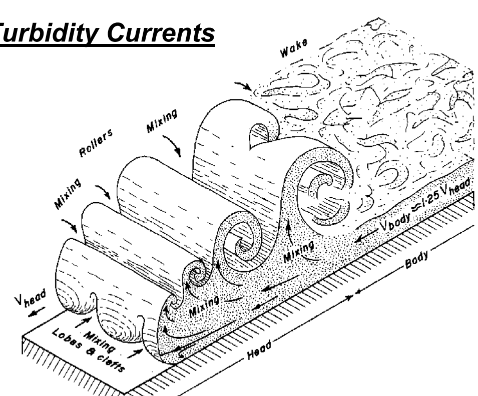


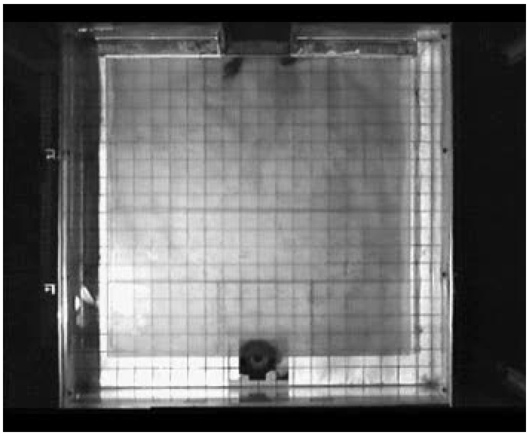
Processes



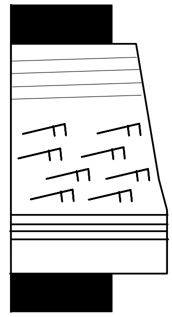
- **Turbidity Currents**
  - **Grains held in suspension by fluid turbulence**
  - **Generated by submarine failures, rivers entering lakes, etc.**
  - **Can transport sediment long distances (100s of km)**
  - **Slow/stop through mixing with ambient water or change of slope**

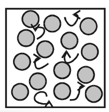
Turbidity Currents





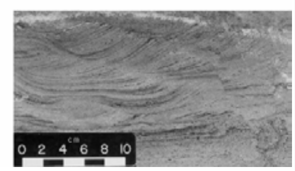
An Ideal Turbidite – “Bouma Sequence”



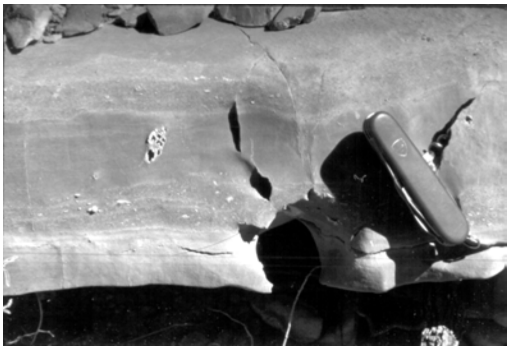


Processes

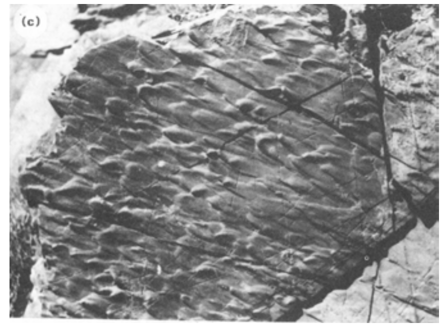
- Turbidites
  - Sedimentary structures record waning currents
  - Commonly normally graded
  - Thickness variable – cm to 10s of cm; tabular beds
  - Complete Bouma Sequences not always developed
    - Use shorthand notation
    - E.g., ABC, BC, A, ACE

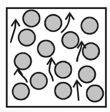


Graded carbonate turbidites – West Texas



Flute marks

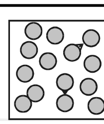




Processes

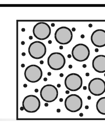
- <u>Fluidized/liquefied flows</u>
  - Grains held in suspension by intergranular flow (loss of grain contacts)
  - Pore fluids escaping upward
  - Loosely packed sands subjected to a shock
  - Flow "freezes" from bottom up as it slows and sediment is redeposited

Dish structures



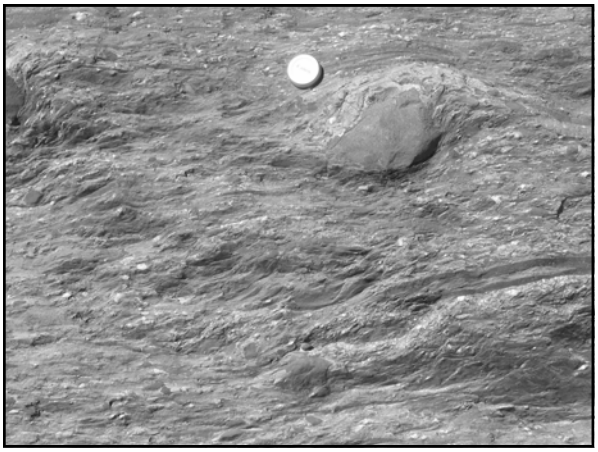
Processes

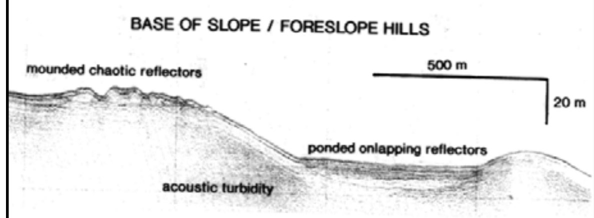
- Grain Flows
  - Grains held in suspension by grain-to-grain collisions (dispersive pressure)
  - Relatively steep slopes
  - Flow "freezes" from bottom up as it slows and sediment is redeposited



Processes

- Debris Flows
  - Grains held in suspension by matrix strength (suspended fines)
  - "Traditionally" thought that clays were needed, now known not to be true
  - Wide range of grain sizes transported if available





Processes

- Four end-member types – gradation from one type to another
  - "Hybrid" flows
  - Changes with time, location
  - Other classification schemes possible
- Most experimental work done in 60s and 70s – new work changing some ideas
- Relatively low submarine slopes needed, & trigger mechanism
- Cohesive mass movements – slides, slumps, etc.

Mass-transport processes			Mechanical behavior	Transport mechanism and sediment support
Rock fall			Elastic	Free fall and subordinate rolling of individual blocks or clasts along steep slopes
Slide		Glide	Elastic	Shear failure among discrete shear planes with little internal deformation or rotation
Slide		Slump	Elastic	Shear failure accompanied by rotation along discrete shear surfaces with little internal deformation
			Plastic limit	
Sediment gravity flow	Mass flow	Debris flow Mud flow	Plastic	Shear distributed throughout sediment mass; strength principally from cohesion due to clay content; additional matrix support possibly from buoyancy
Sediment gravity flow	Mass flow	Grain flows: Inertial / Viscous	Liquid limit	Cohesionless sediment supported by dispersive pressure; flow in inertial (high-concentration) or viscous (low-concentration) regime; steep slopes usually required
Sediment gravity flow	Fluidal flow	Liquefied flow	Viscous fluid	Cohensionless sediment supported by upward displacement of fluid (dilatance) as loosely packed structure collapses, settling into a more tightly packed framework; slopes in excess of 3° required
Sediment gravity flow	Fluidal flow	Fluidized flow	Viscous fluid	Cohesionless sediment supported by the forced upward motion of escaping pore fluid; thin (<10 cm) and short-lived
Sediment gravity flow	Fluidal flow	Turbidity current	Viscous fluid	Supported by fluid turbulence

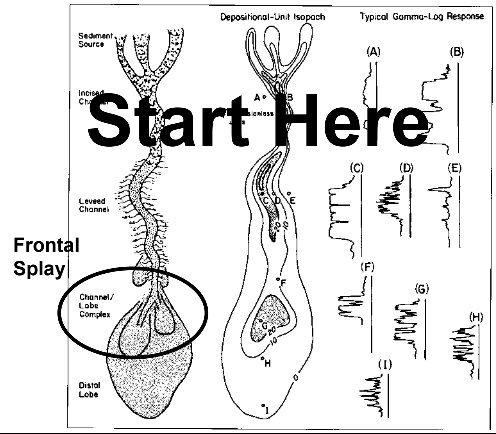
Convolute bedding – West Texas

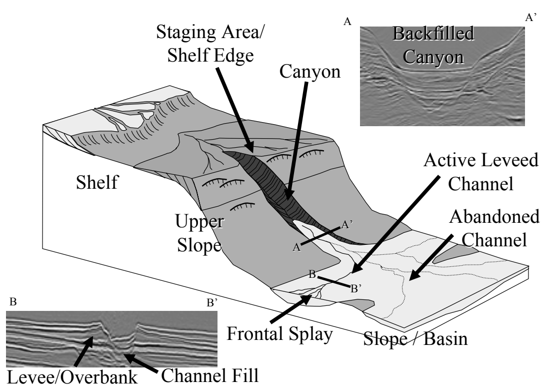
Submarine Fans – Facies Models

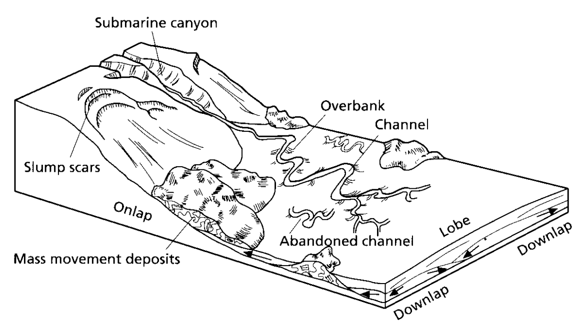
- Knowledge of deep-marine clastic systems based on outcrop, logs and especially imaging/sampling of modern fan systems in 1980s, 1990s
  - Gloria/Seabeam/side-scan sonar
  - 2-D and 3-D seismic images
  - Deep-sea drilling (DSDP, ODP)

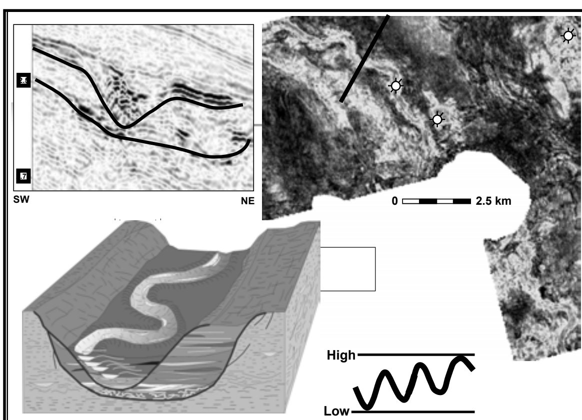
Submarine Fans – Facies Models

- Much more elongate, complex than previously thought
- Main components: incised channels (submarine canyons, slope channels), leveed channel systems, mass transport complexes, frontal splays, distal lobes

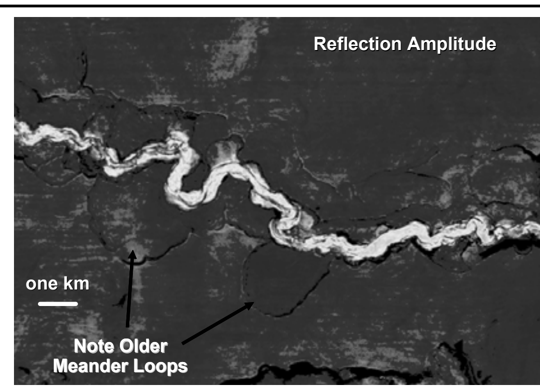






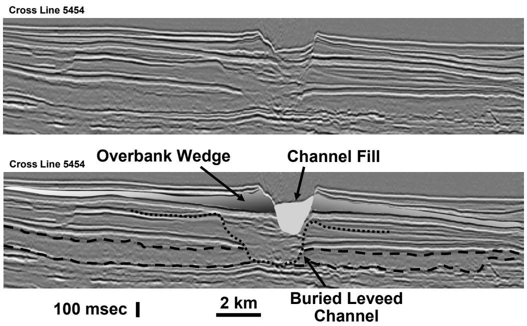


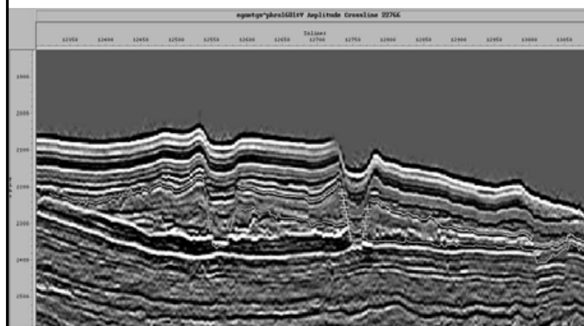
Pliocene slope channels, Nile Delta (Samuel et al., 2003)

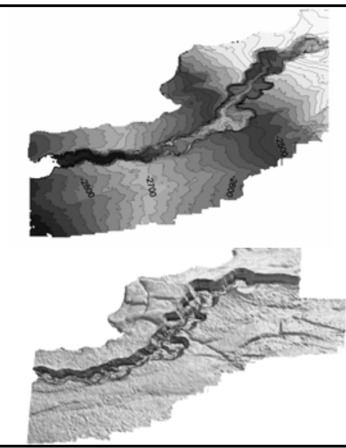


Seafloor – Offshore Nigeria

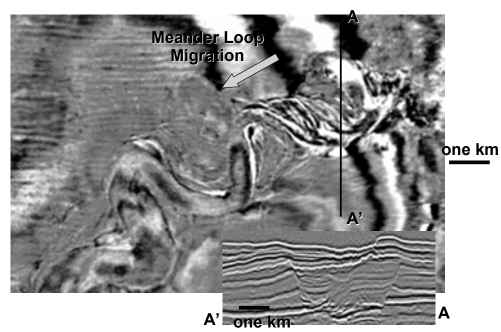
Offshore Nigeria – Pleistocene Leveed Channel

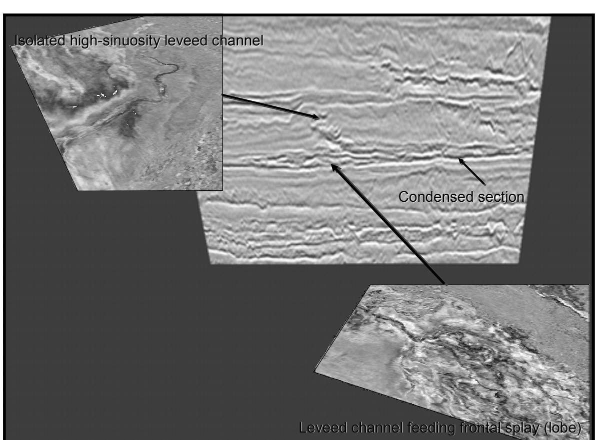


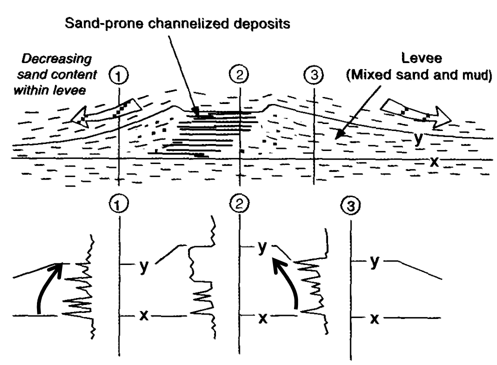


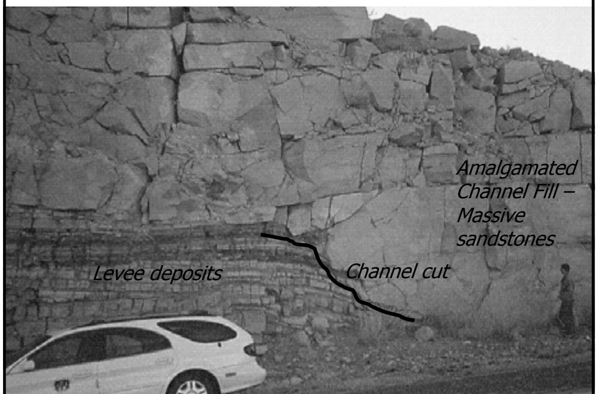


Offshore Nigeria - Shallow Buried Leveed Channel









Levee Deposits

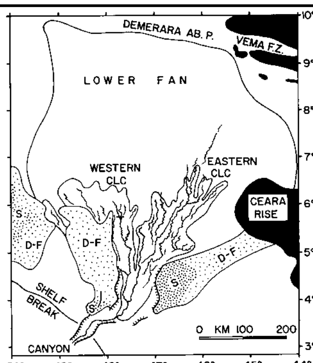


Figure 23 Main components of the Amazon submarine fan in the south Atlantic. S D-F indicates slump/debris flow complexes, and CLC indicates channel-levee complexes. Sinuous lines show positions of the main channels on the fan surface. Fan passes seaward into the Demerara Abyssal Plain, and abuts against the irregular topography of the mid-Atlantic Ridge (black). Short, heavy line toward northern end of the Western channel-levee complex indicates the location of Figure 29.

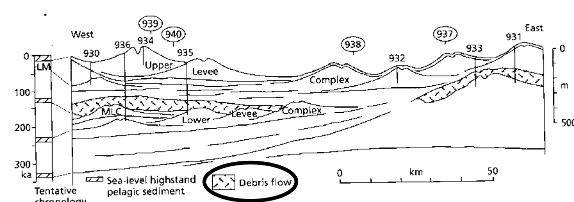
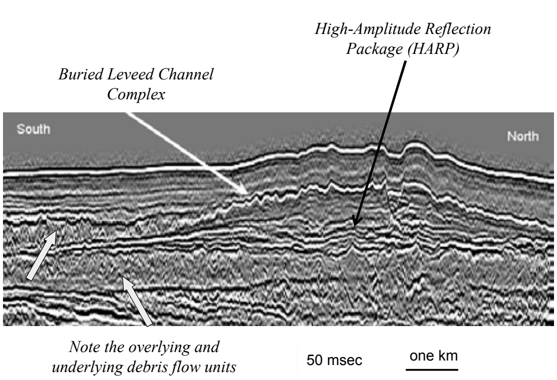


Fig. 26.15 Schematic cross-section of the Amazon fan. Numbers are sites in Fig. 26.14. Note the stacked and offset lowstand channel–levee complexes formed in response to channel switching, and the burial and onlap of the debris flow deposits by fan sediment. MLC, middle levee complex; LM, 30 ka Lake Mungo event. (After Cramp *et al.*, 1995.)

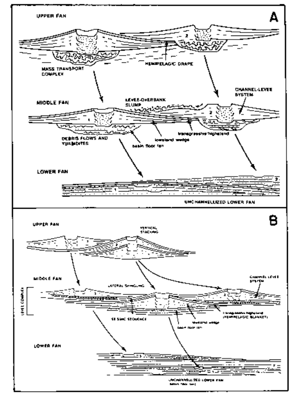


Submarine Fans – Facies Models

- **Channel fills – amalgamated sandstone**
  - **High-amplitude facies**
  - **May show meandering**
- **Levees – interbedded turbidites and shale**
  - **"Gull-wing" geometry**

Submarine Fans – Facies Models

- **Mass transport complexes**
  - **Chaotic facies**
- **Frontal splays – turbidites, “debrites”**
  - **“HARP” – high-amplitude reflection packages**
- **Distal lobes – channel sandstones, turbidites and shale**
  - **Parallel reflections, some channels**



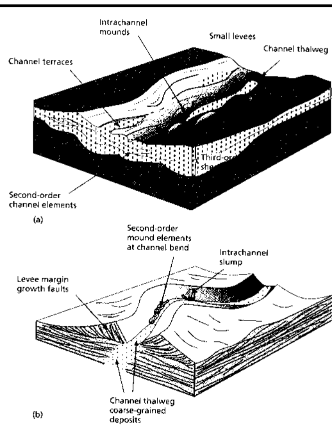
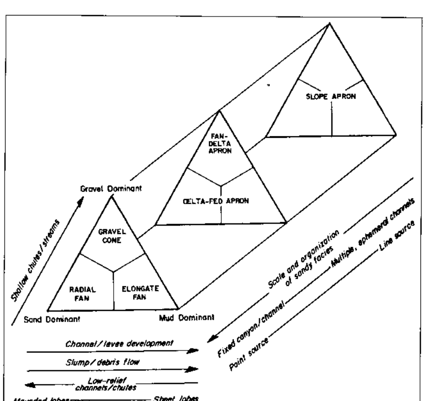


Fig. 26.19 Schematic block diagrams to illustrate contrasting low-sinuosity fan channels producing sheet sands by lateral migration, with high-sinuosity channels with abundant spillover producing ribbon sands in an aggrading package of levee deposits. (After Clark & Pickering, 1996.)

Controls on Submarine Fan Development

- **Line source *vs* point source**
- **Texture (mud, sand, gravel)**
- **Seafloor relief (bathymetry)**
- **Sea level change**



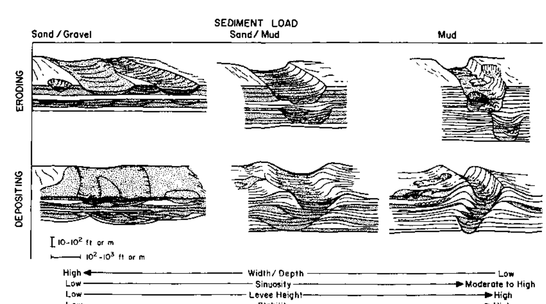
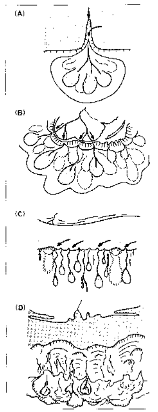


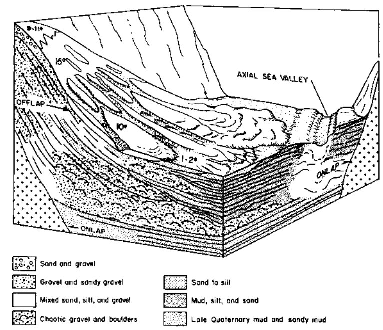
Figure 1—The spectrum of turbidite channels contrasting the geometric and depositional attributes of erosional and depositional types as a function of texture of sediment transported. Correlations among width/depth ratio, sinuosity, levee height, and channel stability and texture are similar to those documented in fluvial channels. (From Galloway and Hobday, 1996.)

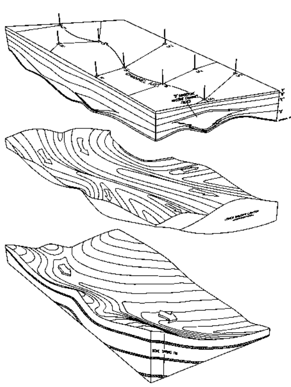


Fans
- Point Source

Aprons
- Line Source

Fan-Delta System





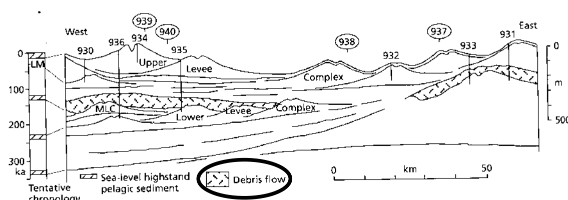
Channel sands in finer-grained deposits

↑

Principle channel axes

↑

Pre-existing (seafloor) relief



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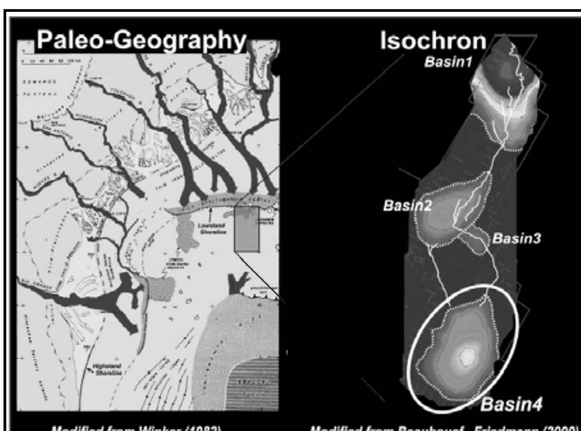
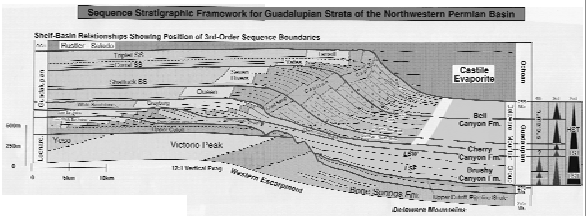
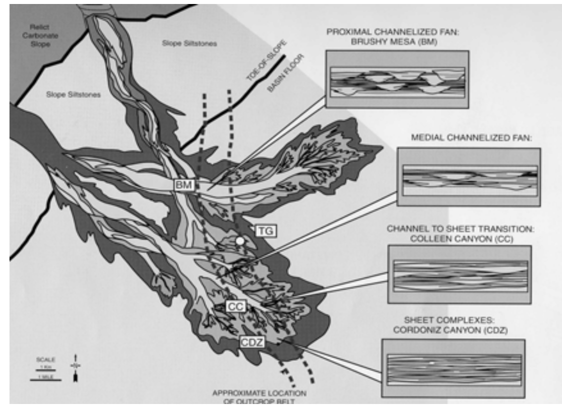
Controls on Submarine Fan Development

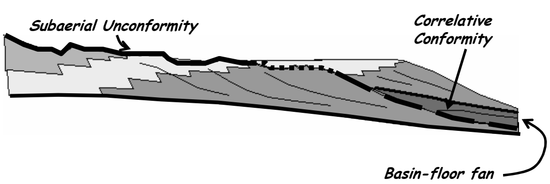
- **Form when sediment can be supplied to shelf margin**
- **Generally when sea level is low**
- **Also if rivers can build deltas across shelf during high sea level, because of high sediment influx (e.g., Mississippi) or narrow shelf (e.g., Congo)**







Sequence boundary is typically placed below the submarine fan



Summary

- Erosion, sediment transport, deposition via density currents in submarine fan systems
  - Slumps and other mass movements possible (mass transport complexes)
- 3-D seismic data, swath bathymetry data useful for studying entire systems
  - Don't show details of sedimentology

Summary

- Principal components:
  - Incised channels (includes submarine canyons, slope channels)
  - Leveed channel systems – amalgamated sands (channels), turbidites (levees)
  - Mass transport complexes – chaotic, convolute bedding
  - Frontal splays – debrites (sandy), turbidites
  - Distal lobes - turbidites

Summary

- Controls on submarine fan development/morphology:
  - Line source *vs* point source (apron *vs* fan)
  - Sediment texture (sand, mud, gravel, mix)
  - Seafloor relief (channel systems usually follow bathymetric lows)
  - Sea level