HURRICANE-INDUCED SEAFLOOR FAILURES IN THE MISSISSIPPI DELTA

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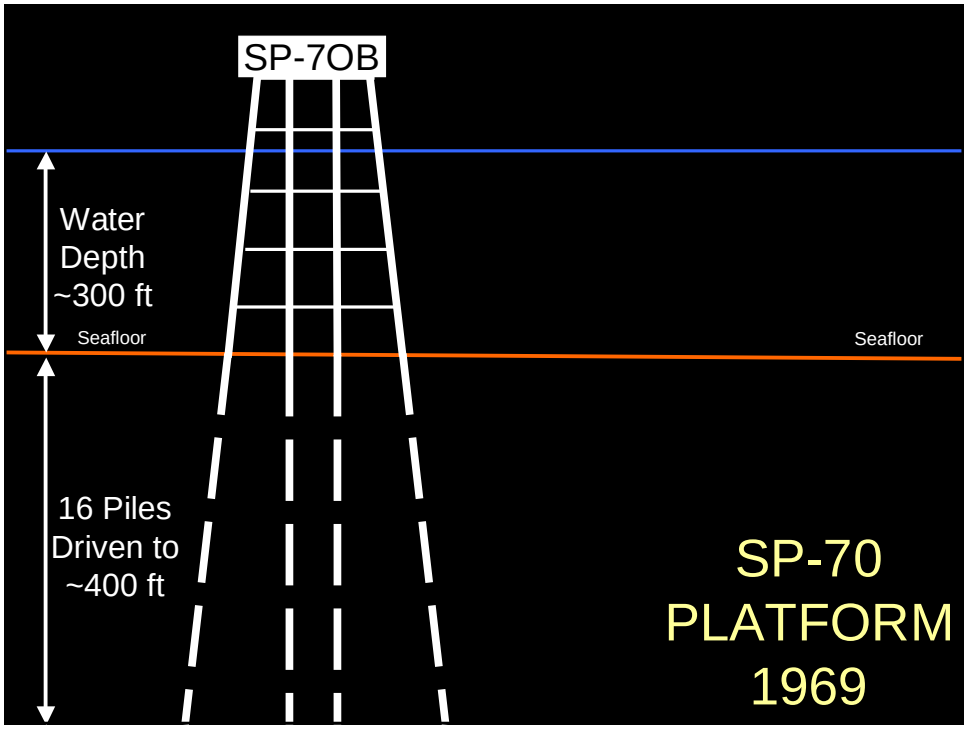
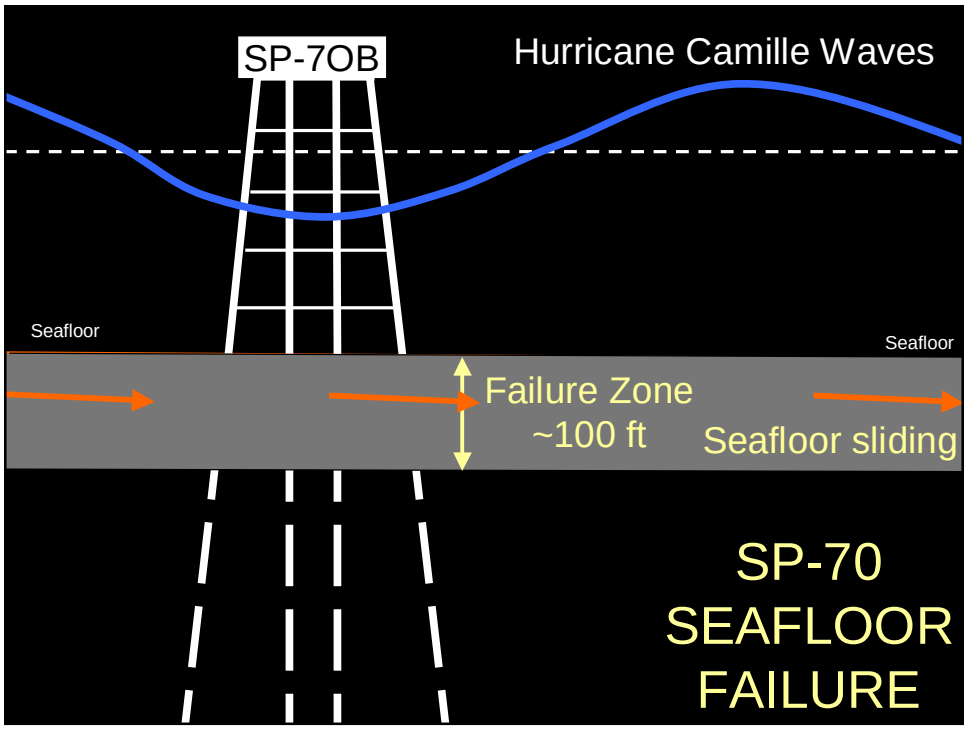
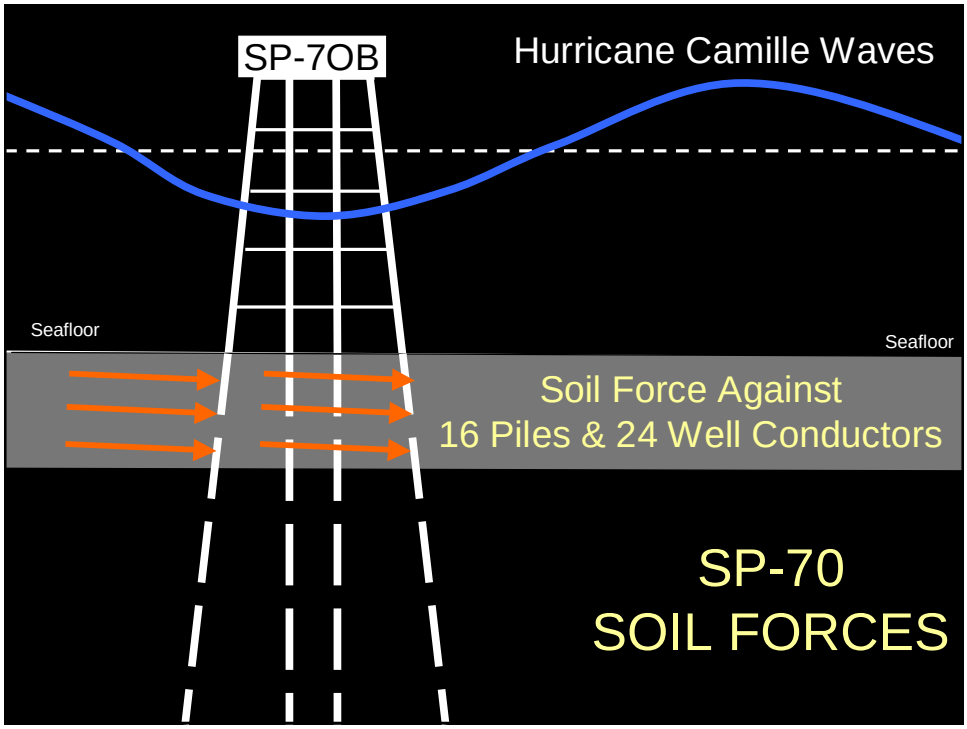
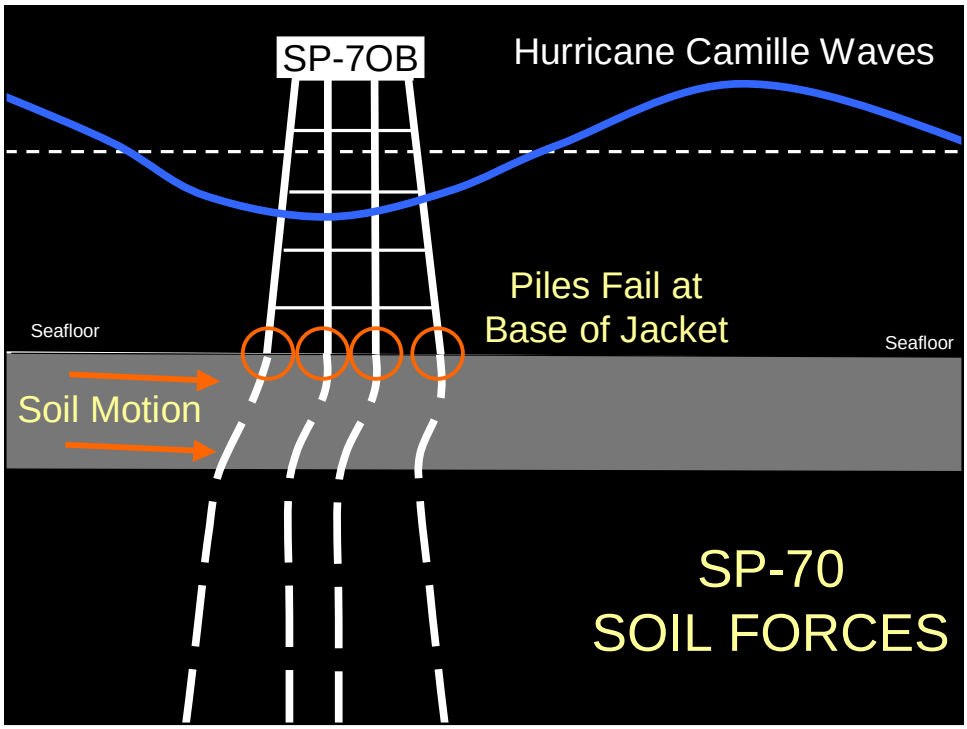
THE DELTA FRONT SEAFLOOR HAS A BAD REPUTATION.

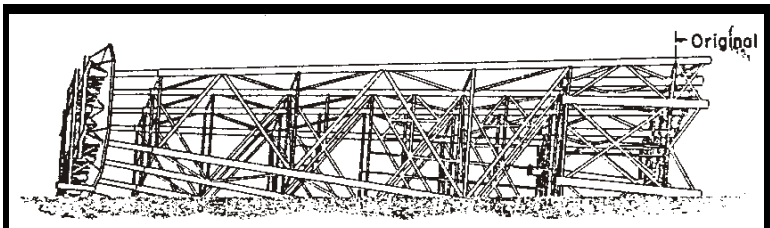
CONSIDER SHELL'S NEW SP-70B PLATFORM SHORTLY AFTER INSTALLATION IN 1969.


SP-7OB
Water
Depth
~300 ft
Seafloor
Seafloor
16 Piles
Driven to
~400 ft
SP-70
PLATFORM
1969

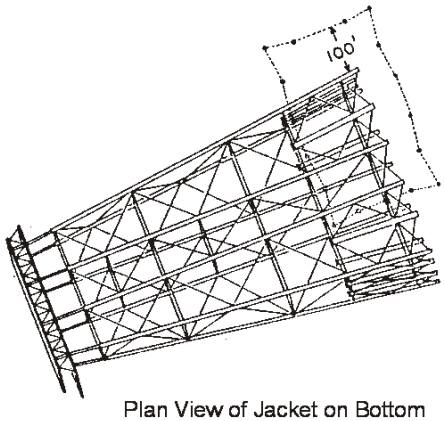

SP-7OB
Hurricane Camille Waves
Seafloor
Seafloor
Failure Zone
~100 ft
Seafloor sliding
SP-70
SEAFLOOR
FAILURE


SP-7OB
Hurricane Camille Waves
Seafloor
Seafloor
Soil Force Against
16 Piles & 24 Well Conductors
SP-70
SOIL FORCES


SP-7OB
Hurricane Camille Waves
Piles Fail at
Base of Jacket
Seafloor
Seafloor
Soil Motion
SP-70
SOIL FORCES



Elevation View of Jacket

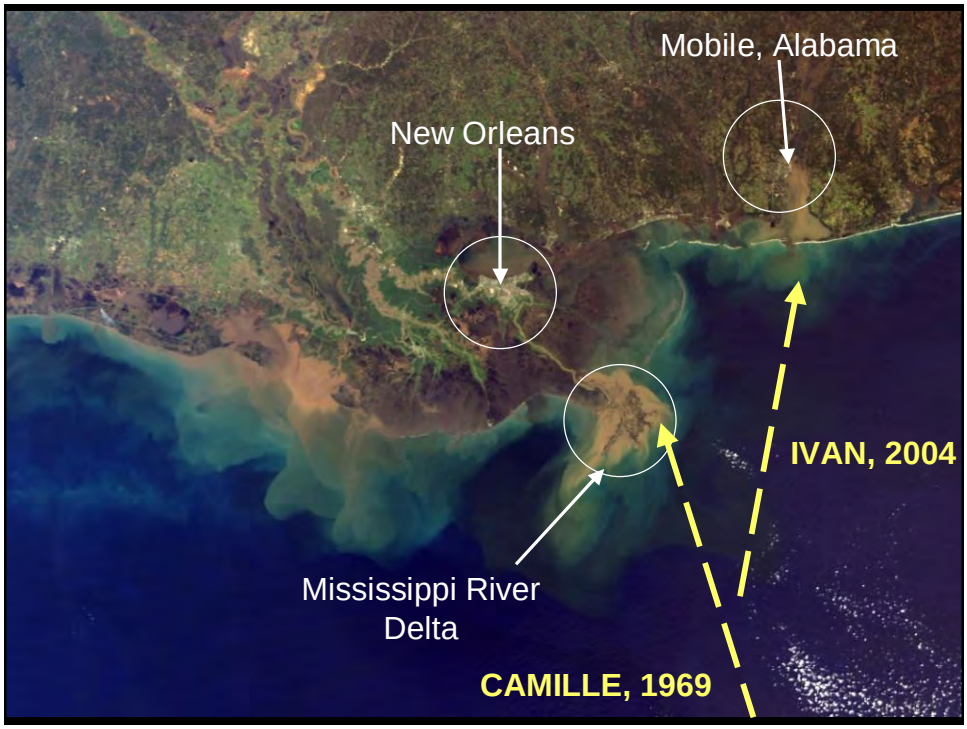


Plan View of Jacket on Bottom

SP-70 PLATFORM FAILURE 1969

MAJOR HURRICANE HISTORY

- 9 major hurricanes (Category 3 or greater) passed near the delta 1900 - 2004.
- *Camille* passed over the delta with a central pressure of **~909 mb**.
- *Ivan* passed east of the delta with a central pressure of **~935 mb**.

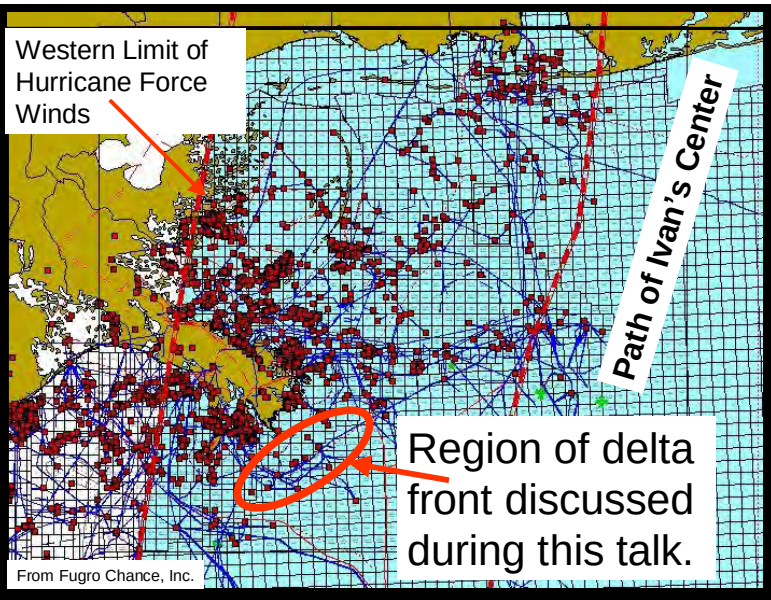


HURRICANE CAMILLE

- South Pass 70 landslides caused the seafloor to move downslope by more than 3000 ft in some areas.
- One new 24-well platform toppled and two others were badly damaged by seafloor landslide failures.
- Pipelines were also damaged and destroyed by landslides.

HURRICANE IVAN 2004

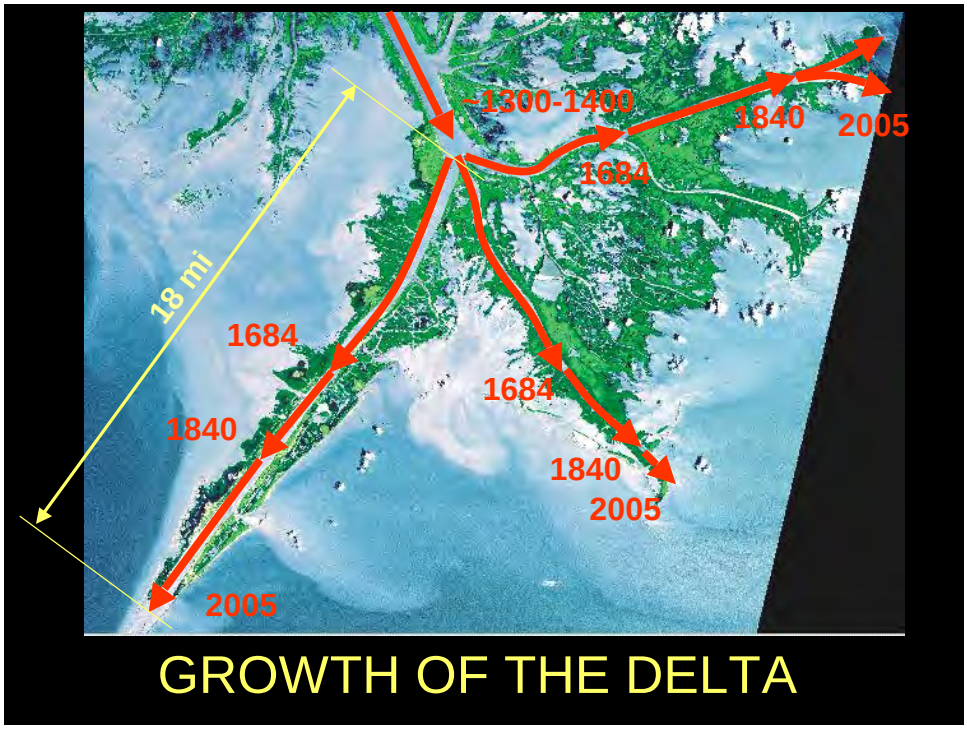
- Delta-front landslides during Ivan were similar in size & character to those experienced during Camille.
- One platform in ~480 ft water depth toppled by landslides (MC-20).
- Pipelines were also damaged and destroyed by landslides.



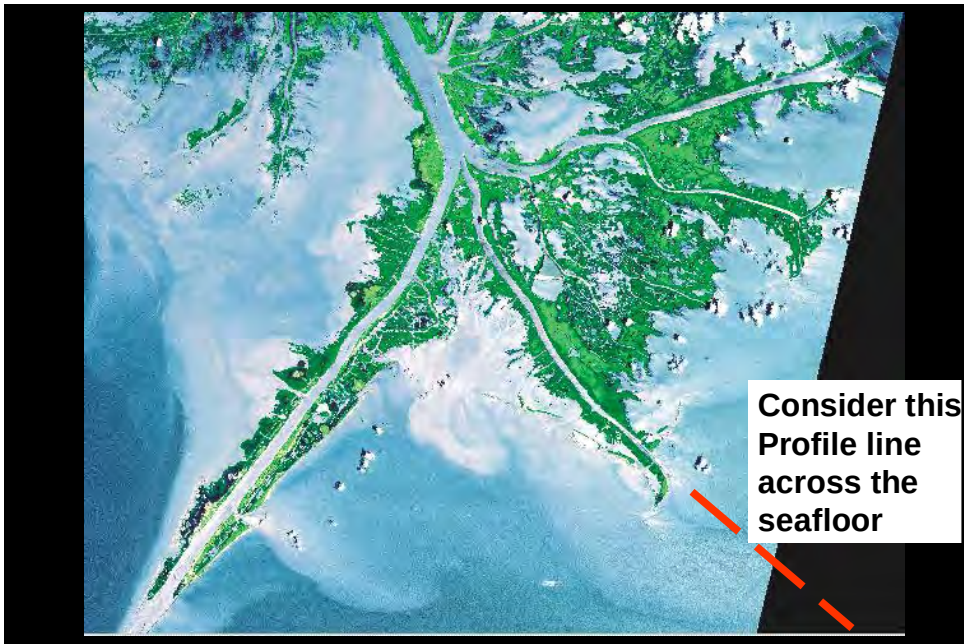
STUDY REGION PLATFORMS AND PIPELINES

WHY IS THE DELTA FRONT PRONE TO SEAFLOOR FAILURES SO DESTRUCTIVE TO PLATFORMS AND PIPELINES ?

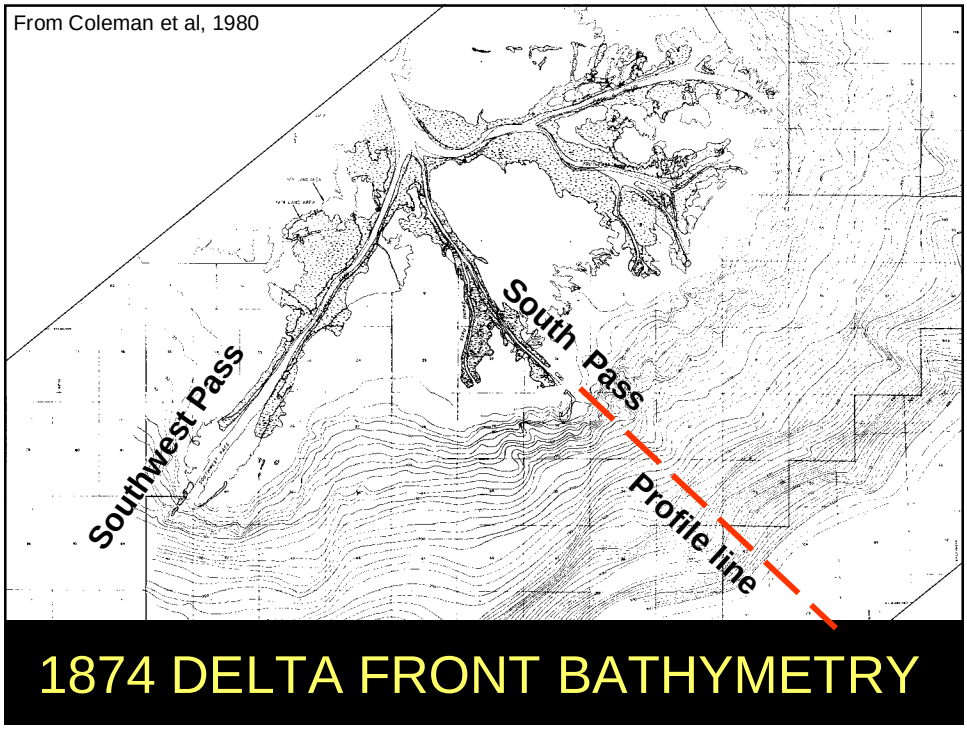
THE BIRDSFOOT DELTA



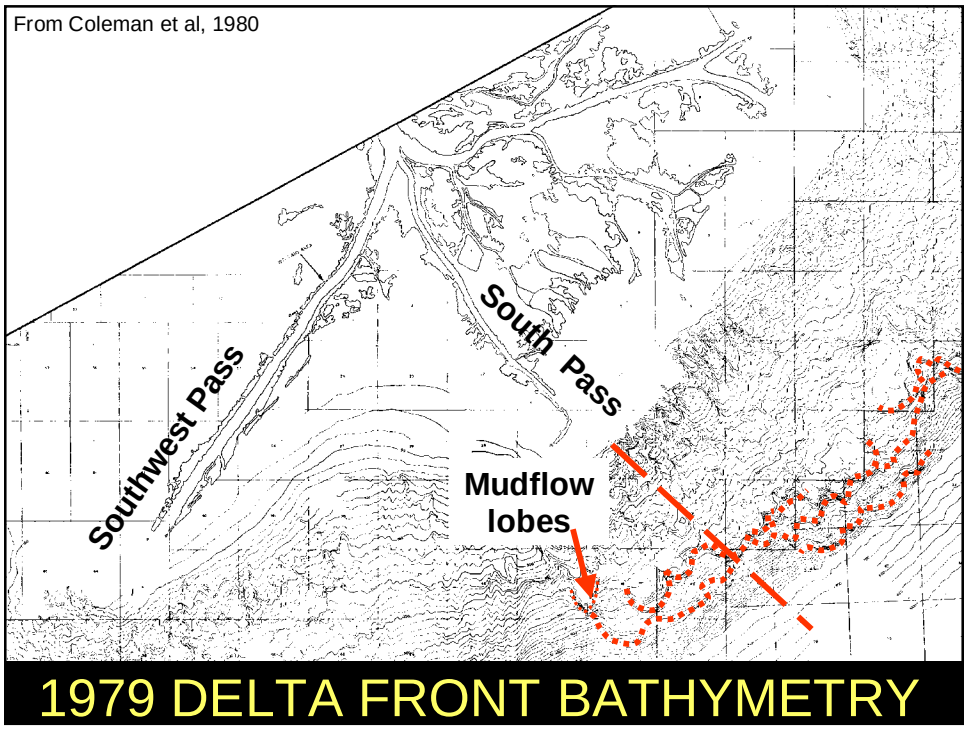
GROWTH OF THE DELTA



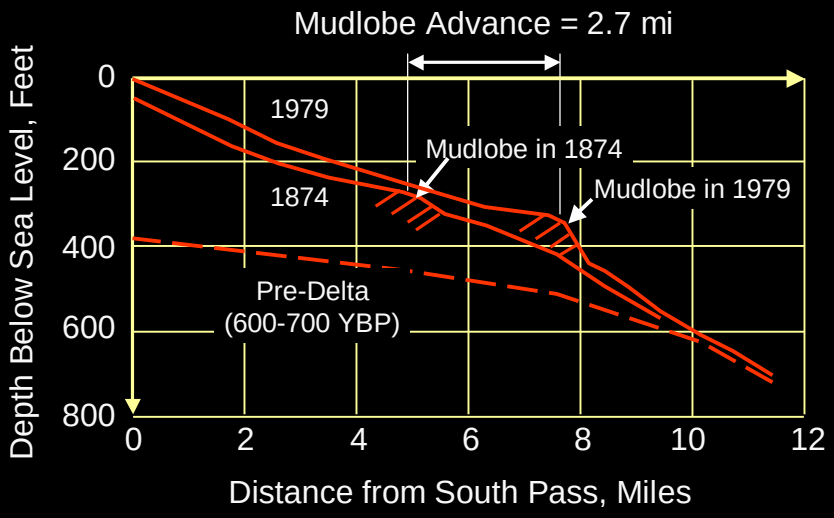
GROWTH OF THE DELTA FRONT



1874 DELTA FRONT BATHYMETRY



1979 DELTA FRONT BATHYMETRY

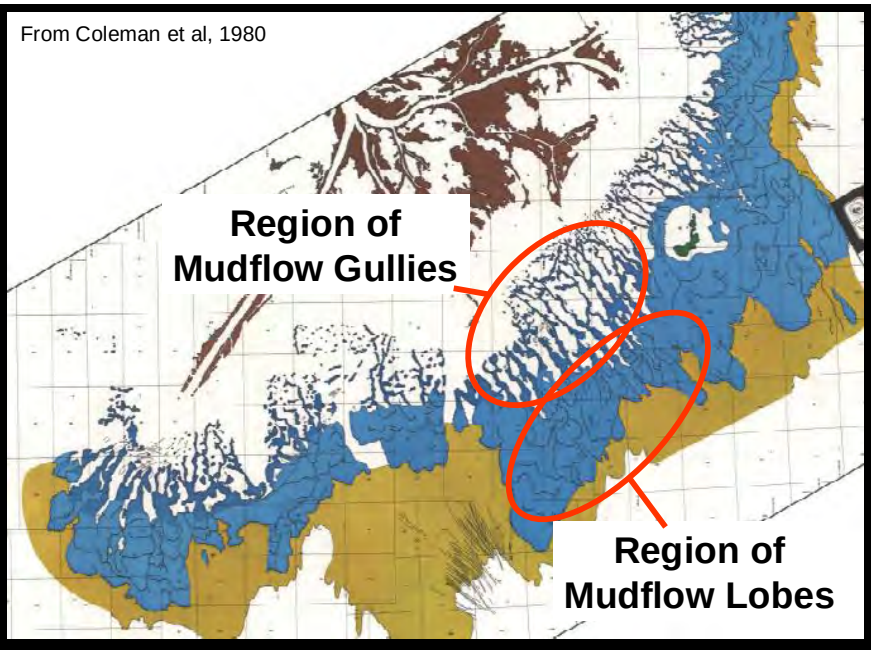


SEAWARD ADVANCE OF THE DELTA

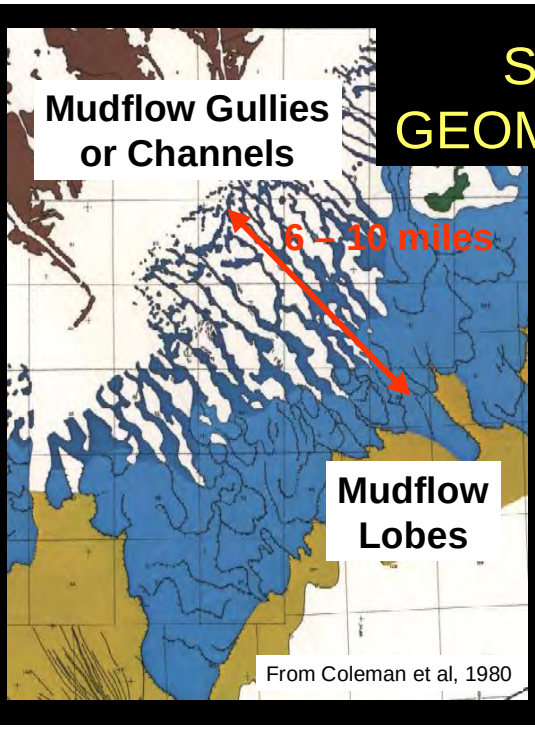
MUDFLOWS MOVE THE DELTA FRONT SEAWARD

DEPOSITION IN THE DELTA

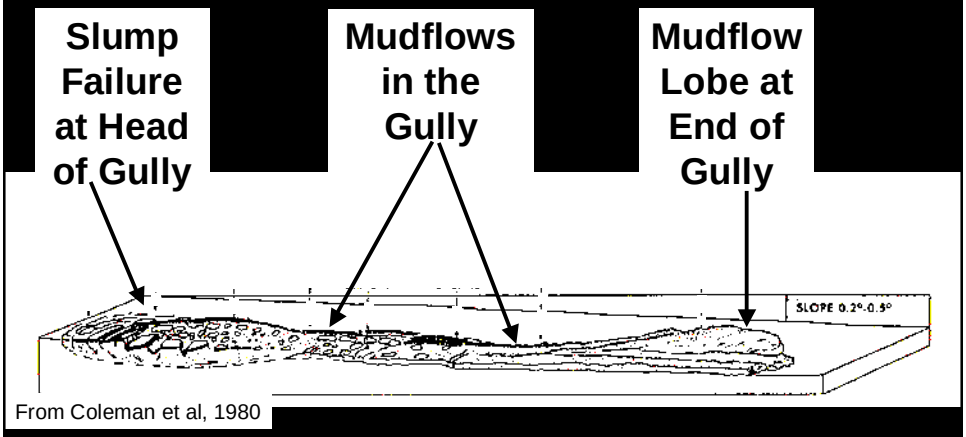
- Deposition rates 1-2 ft/yr in front of the major passes.
- Sediments primarily low permeability clay with silt.
- Results in weak strength profiles more than 300-ft thick, and numerous landslides that create a unique seafloor.



SEAFLOOR GEOMORPHOLOGY



SEAFLOOR GEOMORPHOLOGY

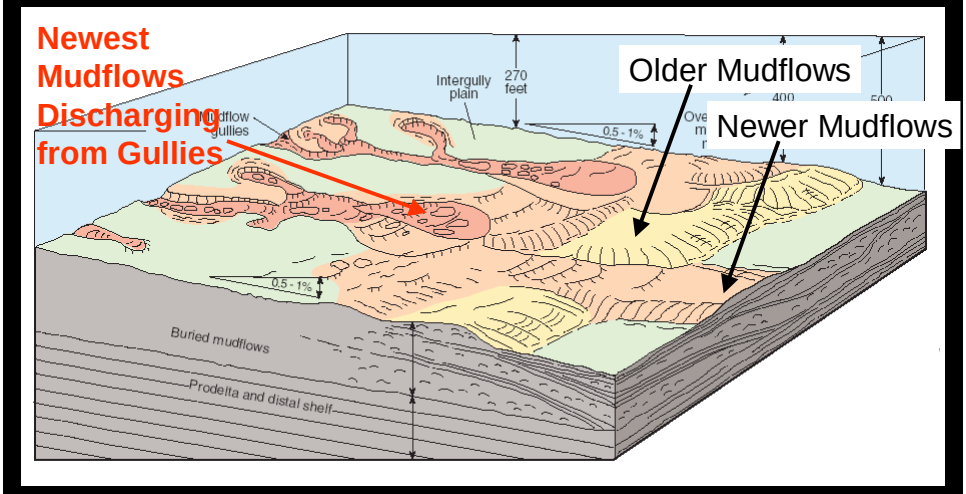


ELONGATE LANDSLIDES

MUDFLOW ORIGIN, SEDIMENT TRANSPORT, AND DEPOSITION

MUDFLOW GULLIES

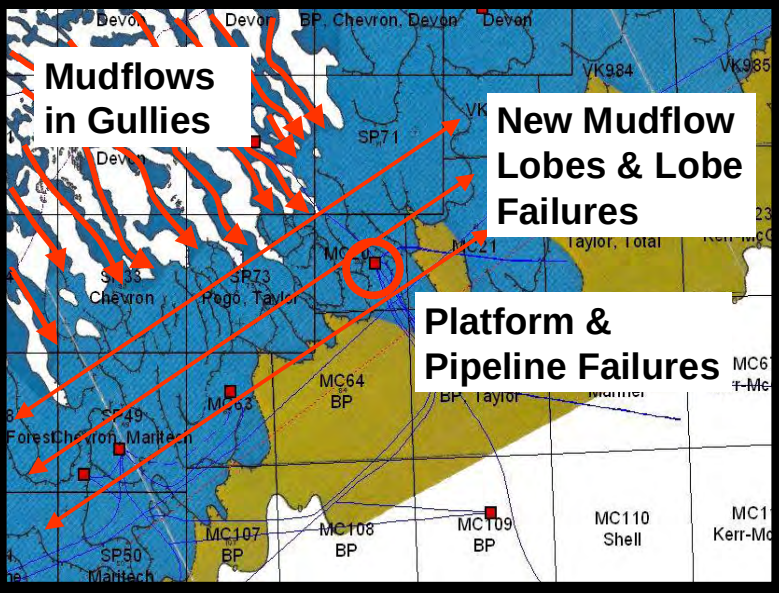
- Mobile sediment typically 40 to 80 feet thick.
- Gully lengths up to 6 miles.
- Major mudflow activity occurs several times a year in some gullies, and every few years in others.



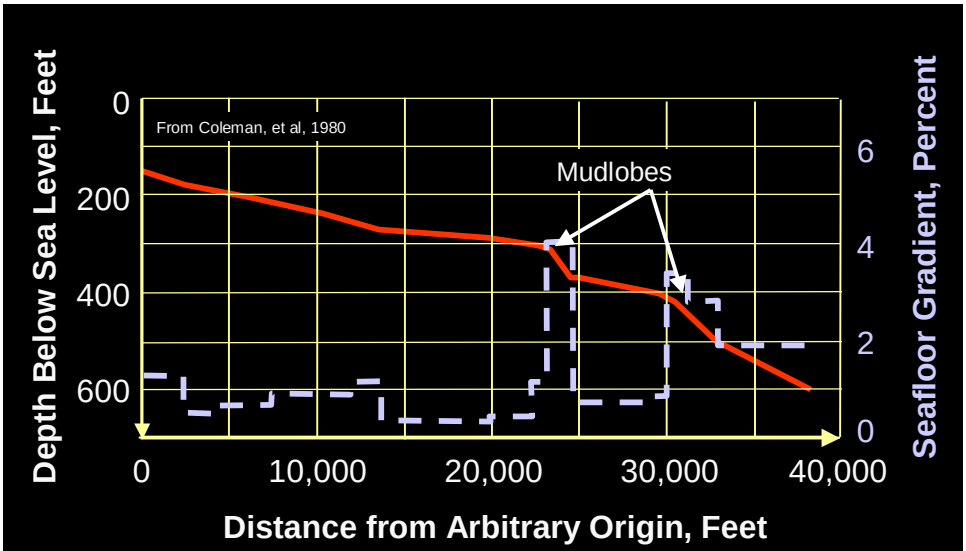
STACKED MUDFLOW ORIGIN

MUDFLOW LOBES

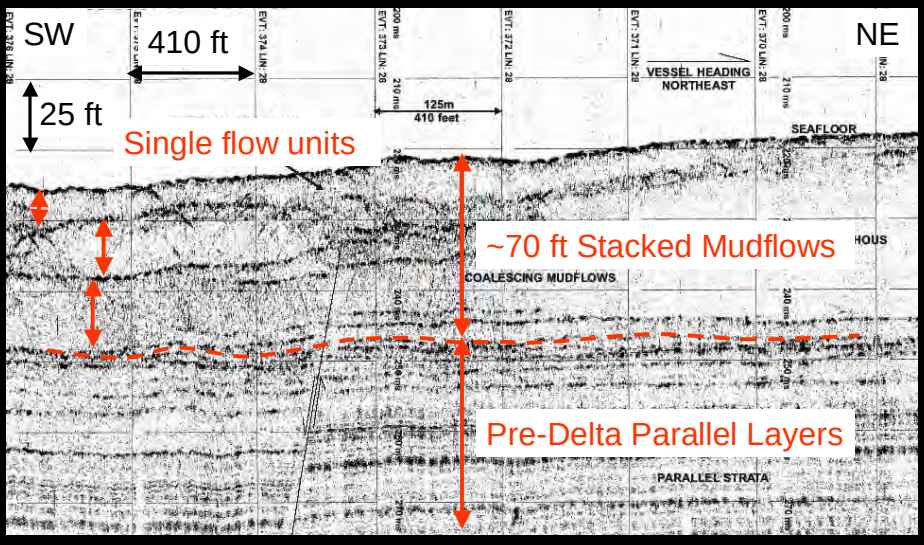
- Individual flow thickness ranges from a few feet to ~50 feet.
- Stacked mudflows are more than 100-ft thick in some areas.
- Mudflow lobes tend to remain stable until triggered by large storm waves.



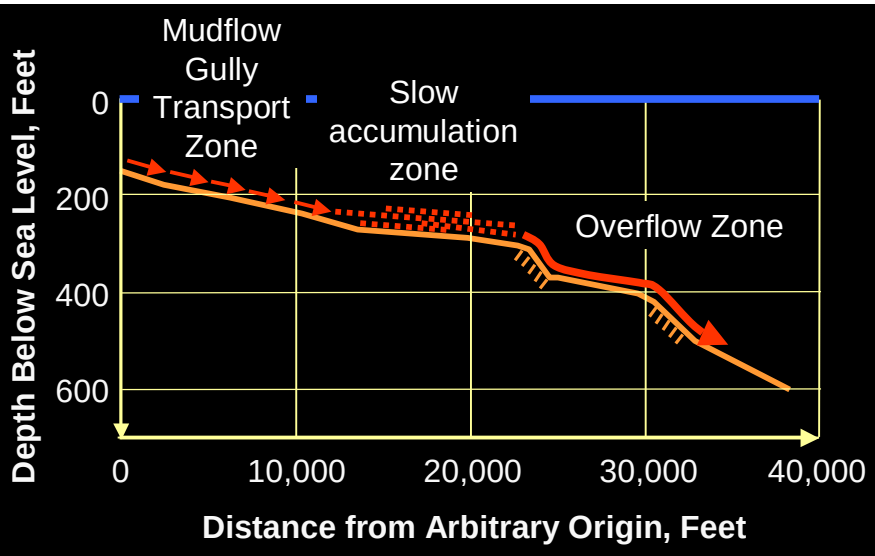
STUDY REGION



SEAFLOOR PROFILE IN SOUTH PASS AREA

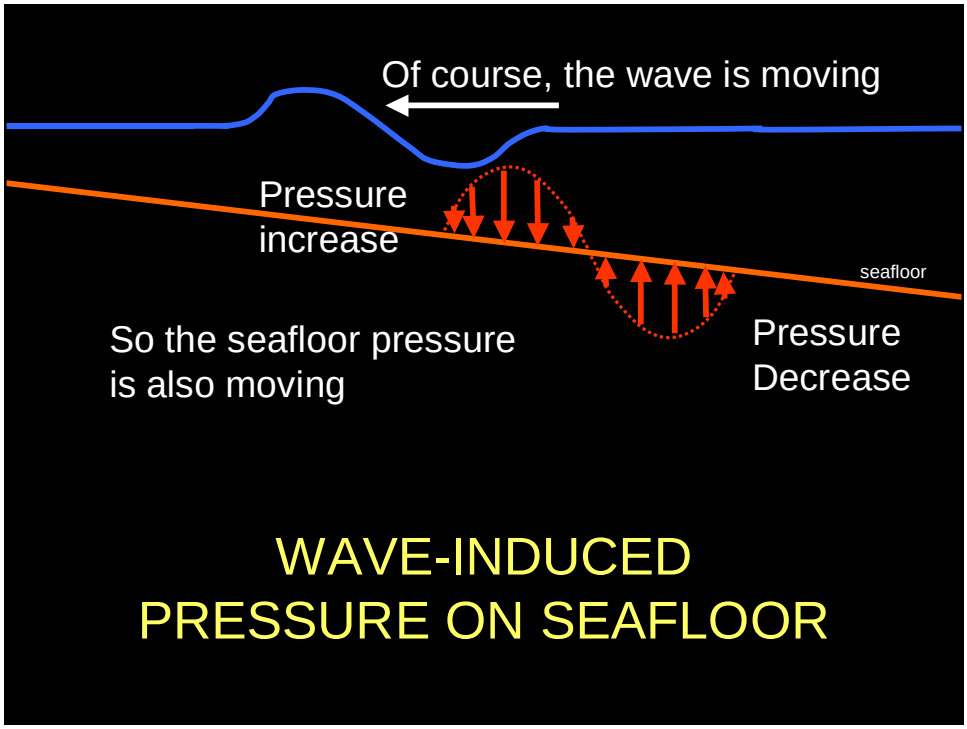


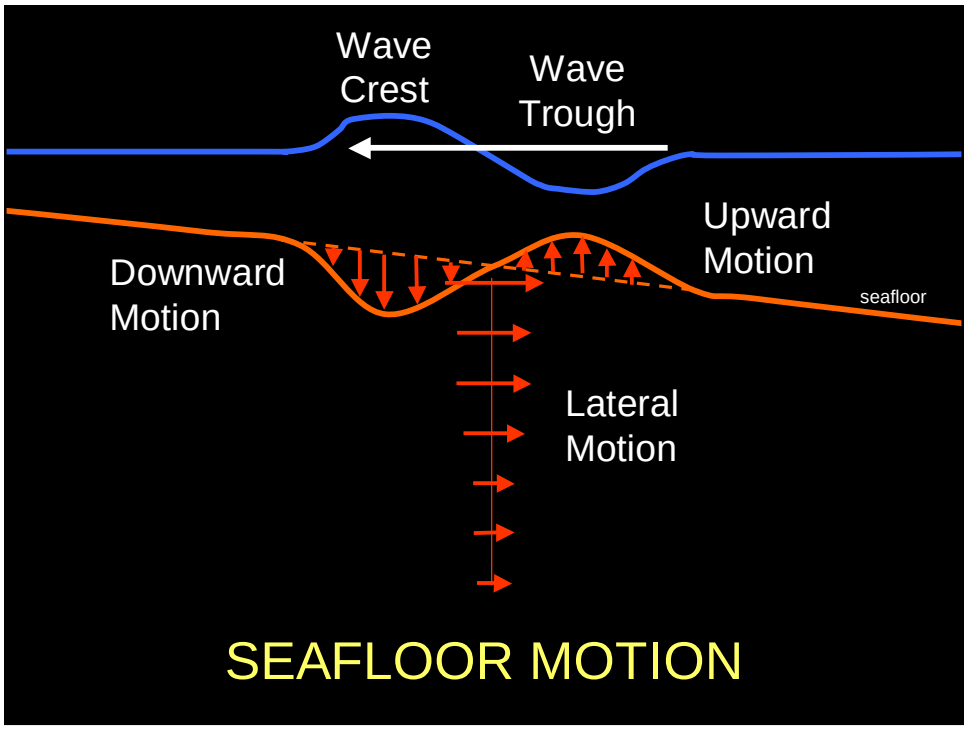
STACKED MUDFLOW EXAMPLE



THE FATE OF MUDFLOW SEDIMENTS

WAVE-TRIGGERED SEAFLOOR FAILURES

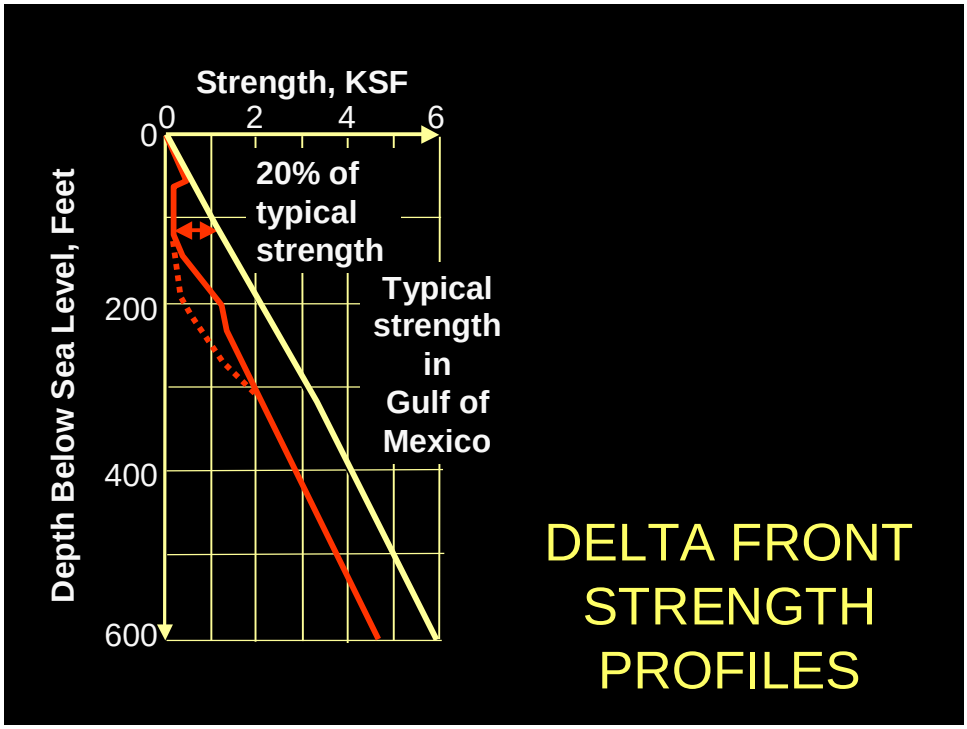

Of course, the wave is moving
Pressure increase
seafloor
So the seafloor pressure is also moving
Pressure Decrease
WAVE-INDUCED PRESSURE ON SEAFLOOR

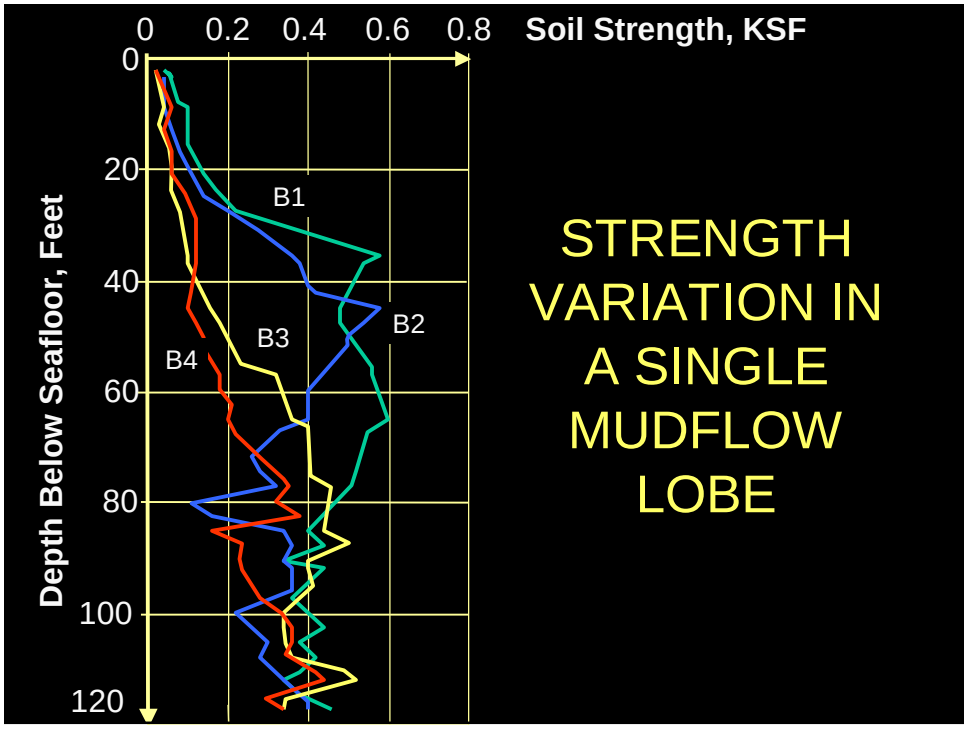

Wave Crest
Wave Trough
Upward Motion
Downward Motion
seafloor
Lateral Motion
SEAFLOOR MOTION

CYCLIC WAVE-BOTTOM PRESSURES

- Cyclic pressure & sediment motion beneath the waves gradually weakens the sediment.
- Weak sediment in the gullies slowly moves downslope during a storm.
- Cyclic pressures may cause slope failure of some mudflow lobes.

SEDIMENT STRENGTH

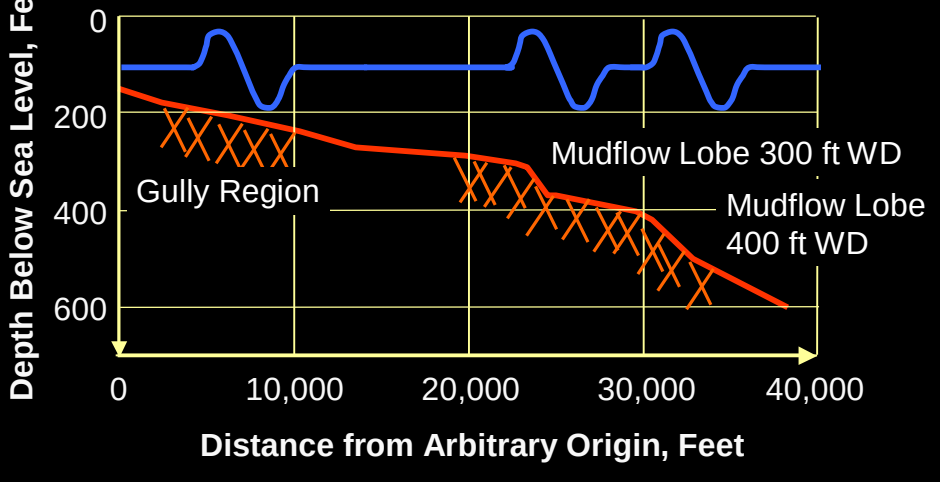

Strength, KSF
0
2
4
6
0
200
400
600
Depth Below Sea Level, Feet
20% of typical strength
Typical strength in Gulf of Mexico
DELTA FRONT STRENGTH PROFILES


0
0.2
0.4
0.6
0.8
Soil Strength, KSF
0
20
40
60
80
100
120
Depth Below Seafloor, Feet
B1
B2
B3
B4
STRENGTH VARIATION IN A SINGLE MUDFLOW LOBE

THIS STRENGTH VARIABILITY IS TYPICAL OF MUDFLOW LOBES

STRENGTH PROFILES FOR SLOPE STABILITY

STABILITY ANALYSES



TYPICAL SEAFLOOR PROFILE

RESULTS OF STABILITY ANALYSES

- Moderate-size waves can fail the sediments in mudflow gullies.
- Mudflow Lobes with Upper-Bound strength profiles appear to be stable during intense hurricanes.
- Mudflow Lobes with Lower-Bound strength profiles appear to fail during intense hurricanes.

SUMMARY

1. Sediments accumulate in shallow water and, over time, move downslope in gullies as mudflows.
2. These gully mudflows are triggered by waves typical of small to large hurricanes.

SUMMARY (cont.)

3. Intense hurricanes (e.g., Ivan and Camille) create large waves causing large pressures on the seafloor.
4. During Ivan/Camille-size storms, existing mudflow lobes may fail, and mudflows from gullies may overrun previously deposited mudflow lobes.

SUMMARY (cont.)

5. Large-scale seafloor failures are the primary geologic process for seaward growth of the delta.
6. Past rates of seaward growth of the delta front will likely be maintained, and seafloor failures will continue to occur.