

# Lecture Presentation

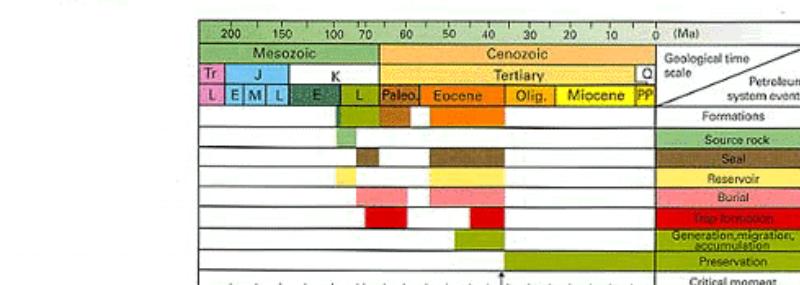
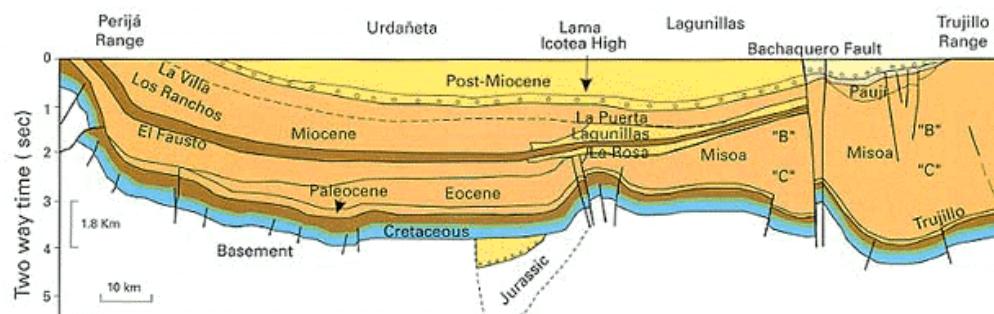
## Basic and Advanced Formation Evaluation

### Geological Models and Outcrop Analogues

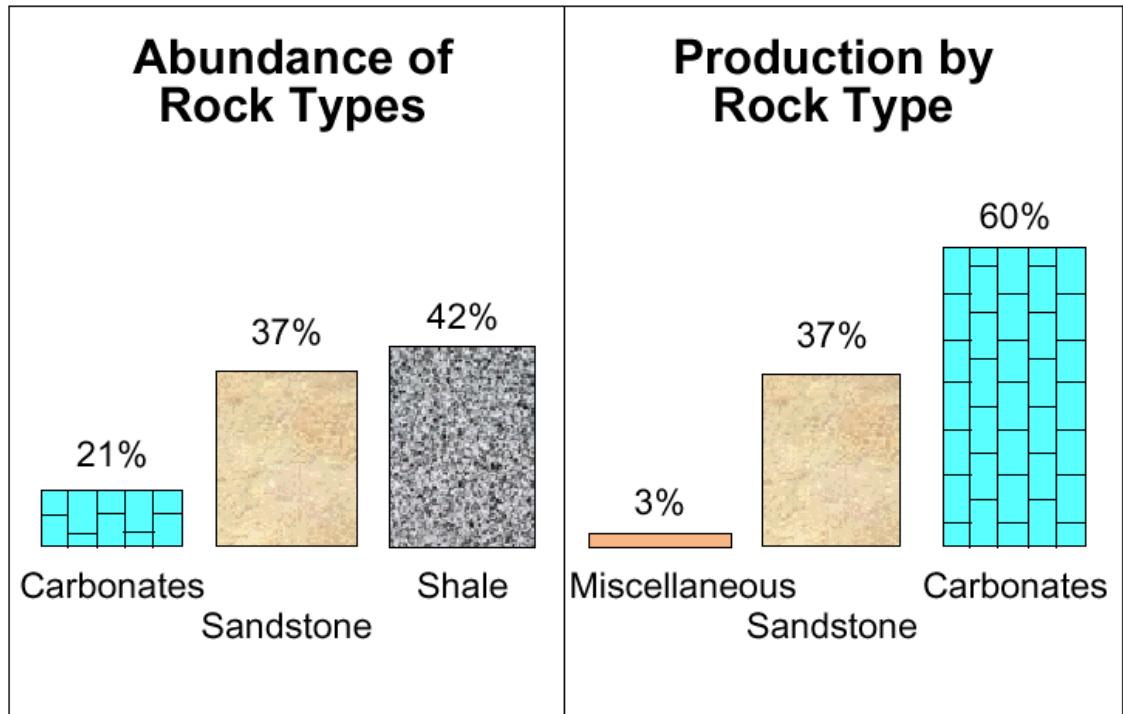
Carlos Torres-Verdín, PhD  
Professor

Hildebrand Department of Petroleum and Geosystems Engineering  
The University of Texas at Austin

### The Petroleum System: Source Rock, Hydrocarbon Kitchen, Migration, Reservoir Rock, and Trap



## Abundance of Rock Types, and Production



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## Rocks Can Be Very Complex!



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## Clastic Rocks are Made of Grain Packs



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## Clastic Rocks are Made of Grain Packs



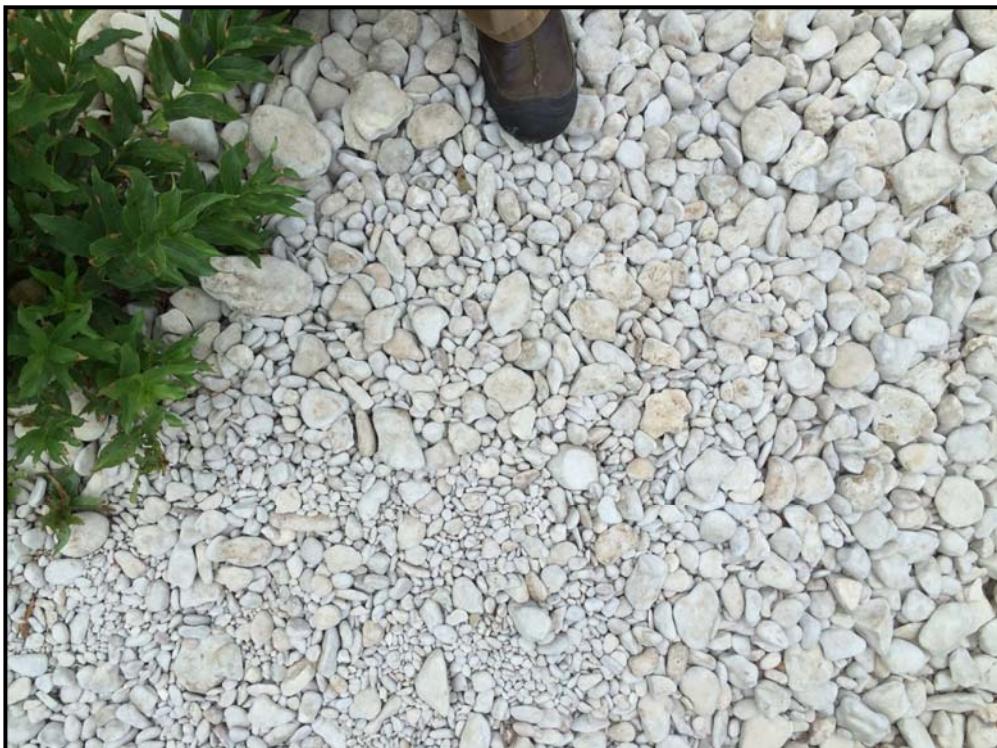
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## Clastic Rocks are Made of Grain Packs



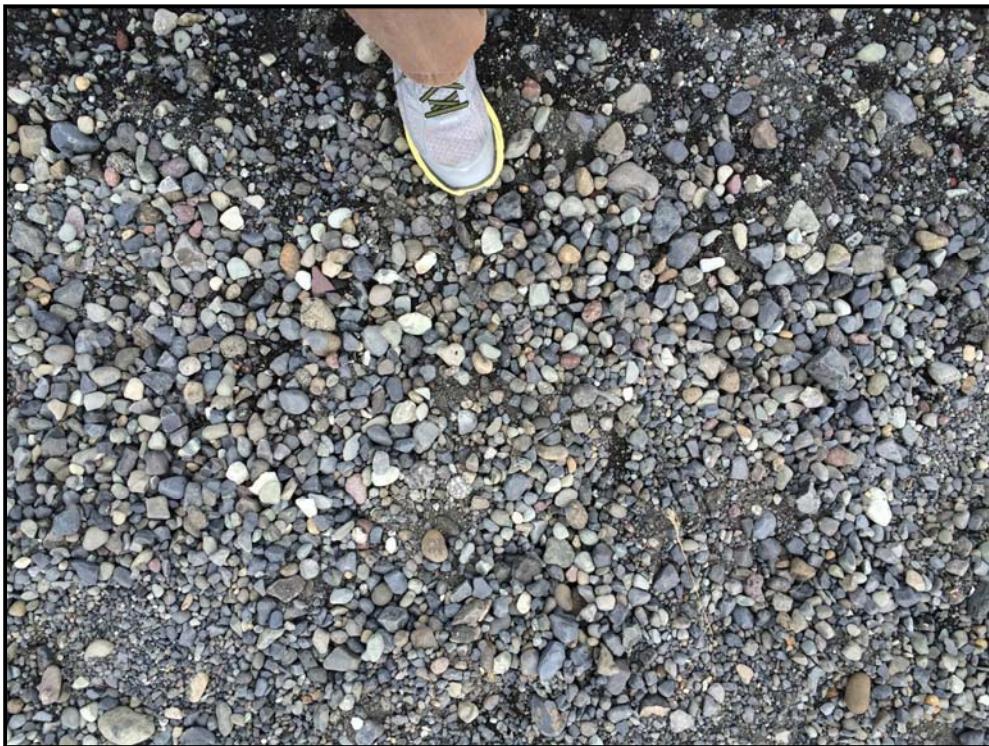
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## Clastic Rocks are Made of Grain Packs



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## Clastic Rocks are Made of Grain Packs



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Carbonate Rocks Are Not Made of  
Grain Packs

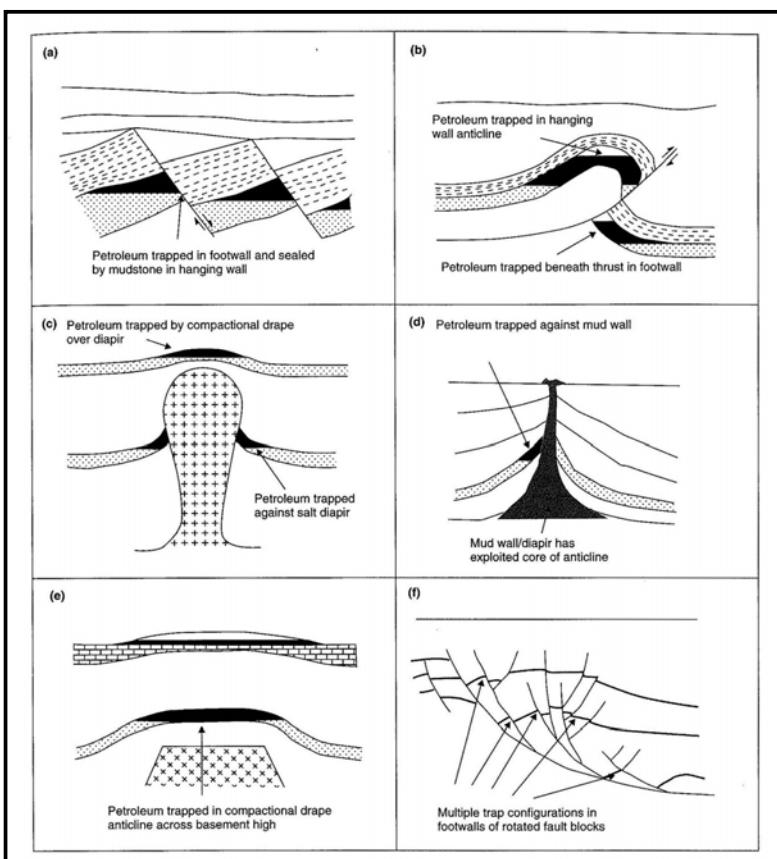


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# Geological Conditioning of Hydrocarbon Reservoirs:

1. Depositional system
2. Diagenesis
3. Structural deformation
4. Migration of fluids from source rock
5. Activation and re-activation of traps (flow seals)
6. History of chemical alteration of fluids due to leaching and variable pressure and temperature conditions.

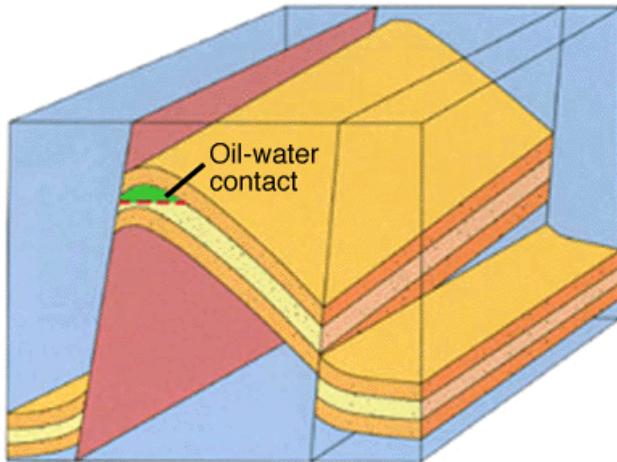
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Examples of  
**STRUCTURAL**  
Hydrocarbon  
Traps

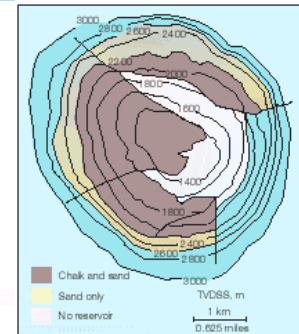
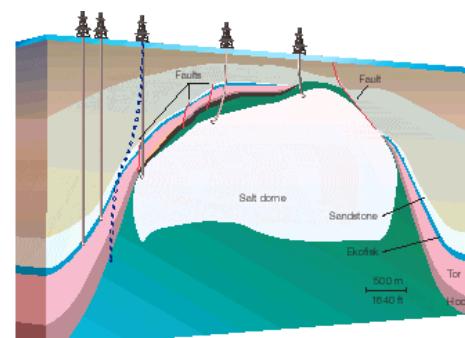
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## Examples of Hydrocarbon Traps



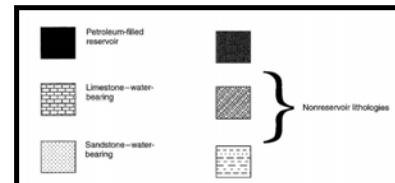
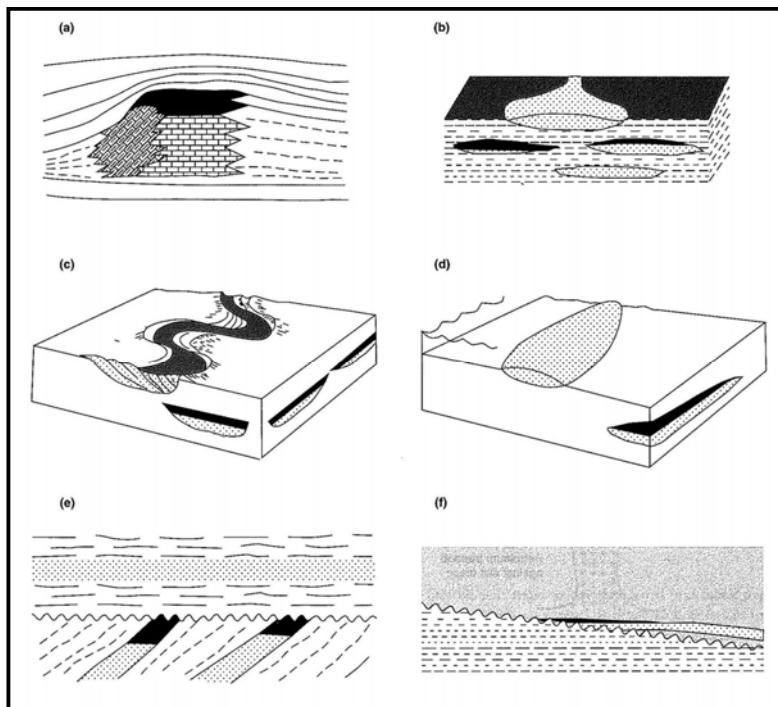
Sealing Fault and Anticline

Salt Dome



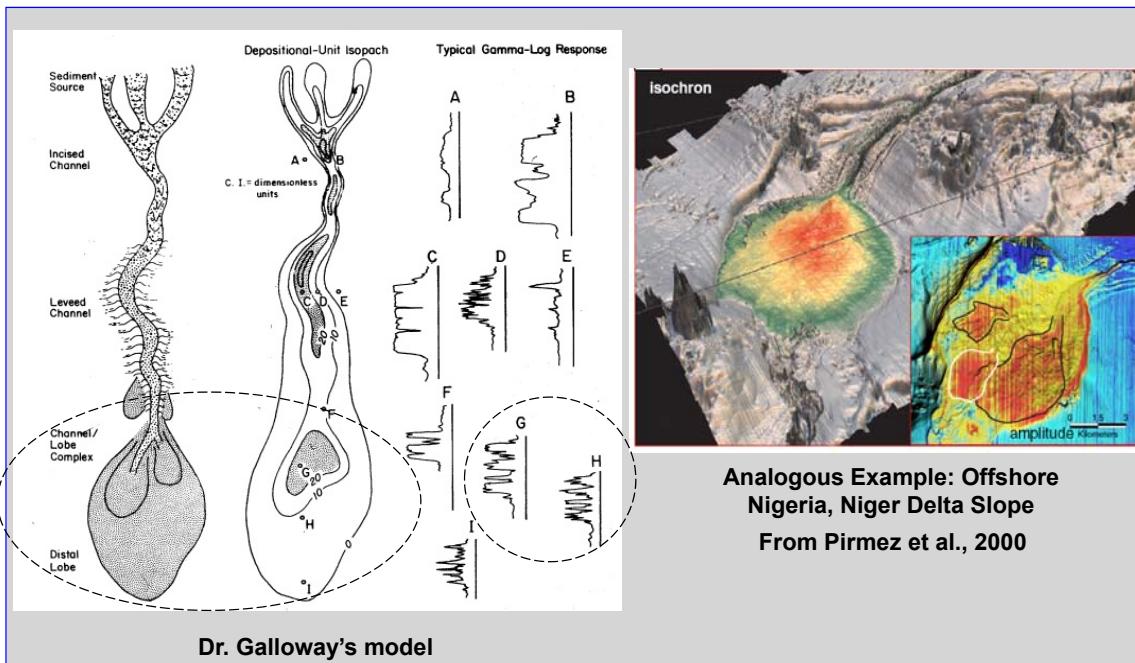
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## Examples of STRATIGRAPHIC Hydrocarbon Traps



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# Geological/Depositional Model



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# Geological/Depositional Model



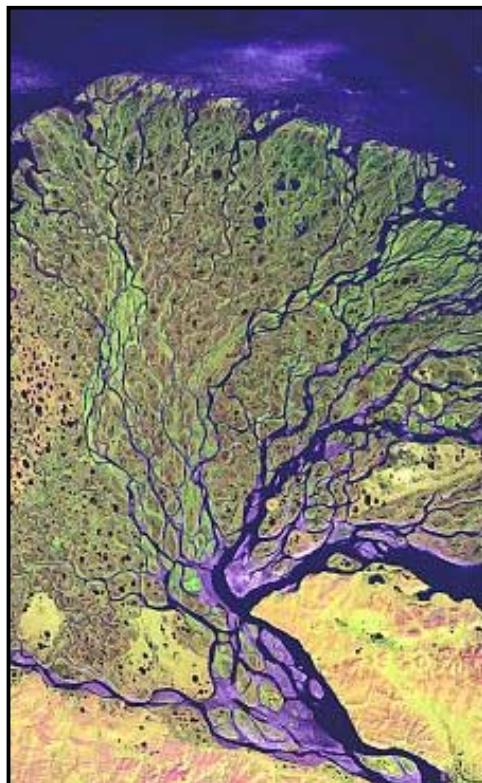
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## Geological/Depositional Model



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## Geological/Depositional Model



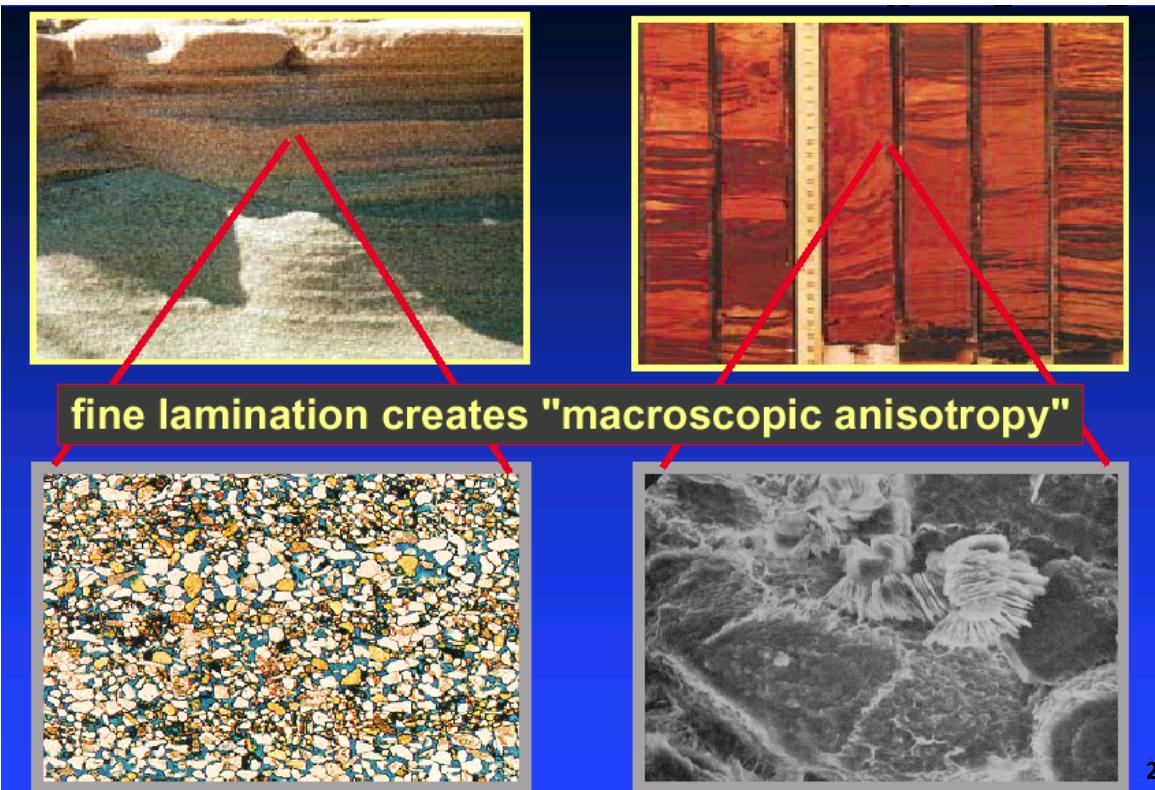
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# Geological Factors that Determine the Quality (Storage and Producibility) of a Hydrocarbon Reservoir:

1. Vertical and lateral extent. Spatial continuity of lithology units and petrophysical properties
2. Grain sorting and cementation; spatial variability
3. Diagenetic history
4. Structural and/or stratigraphic traps, flow barriers
5. History of fluid transport
6. Migration of fluids from source rock

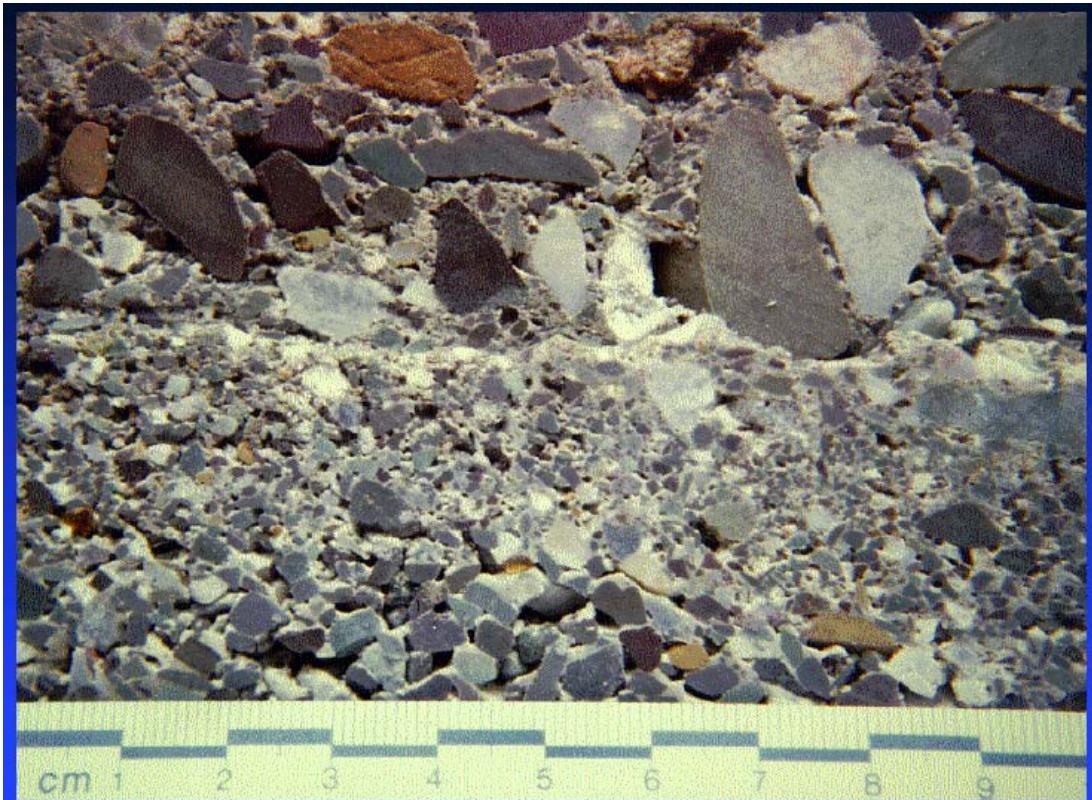
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## Rocks are Heterogeneous and Structured Systems



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## Rocks are Heterogeneous and Structured Systems



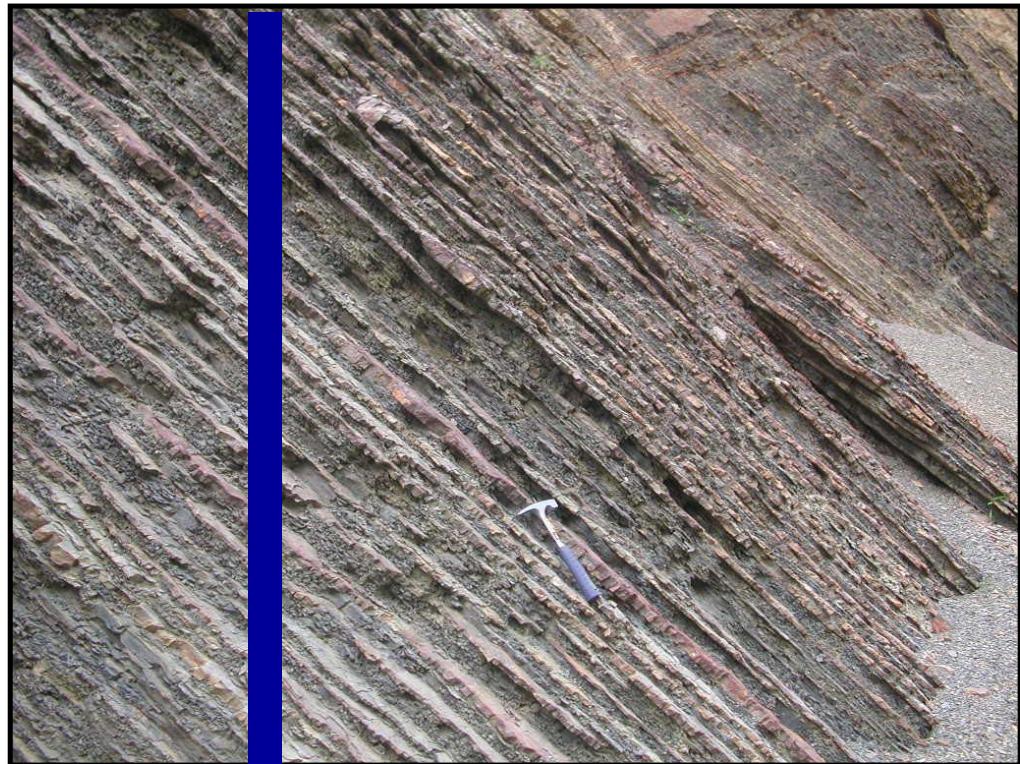
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## Structural and Stratigraphic Frameworks



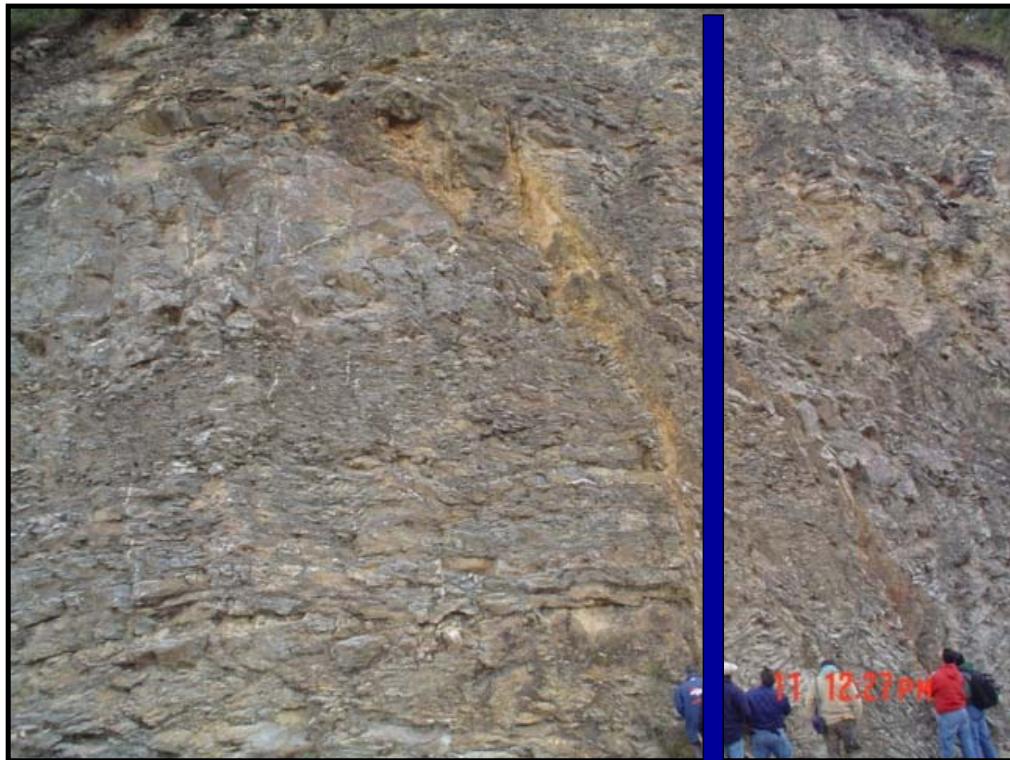
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## Structural Framework and Bed Thickness



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## Fault Interpretation



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## Structure, Bedding, and Texture in Carbonates



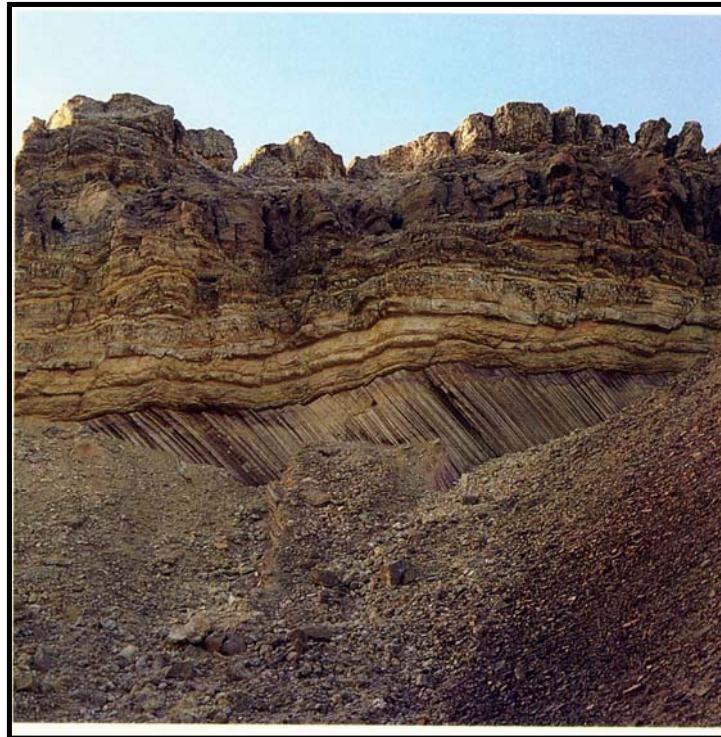
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## Example of Tectonically Deformed Carbonates



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## Example: Angular Unconformity



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## Example of Stratigraphic Unconformity



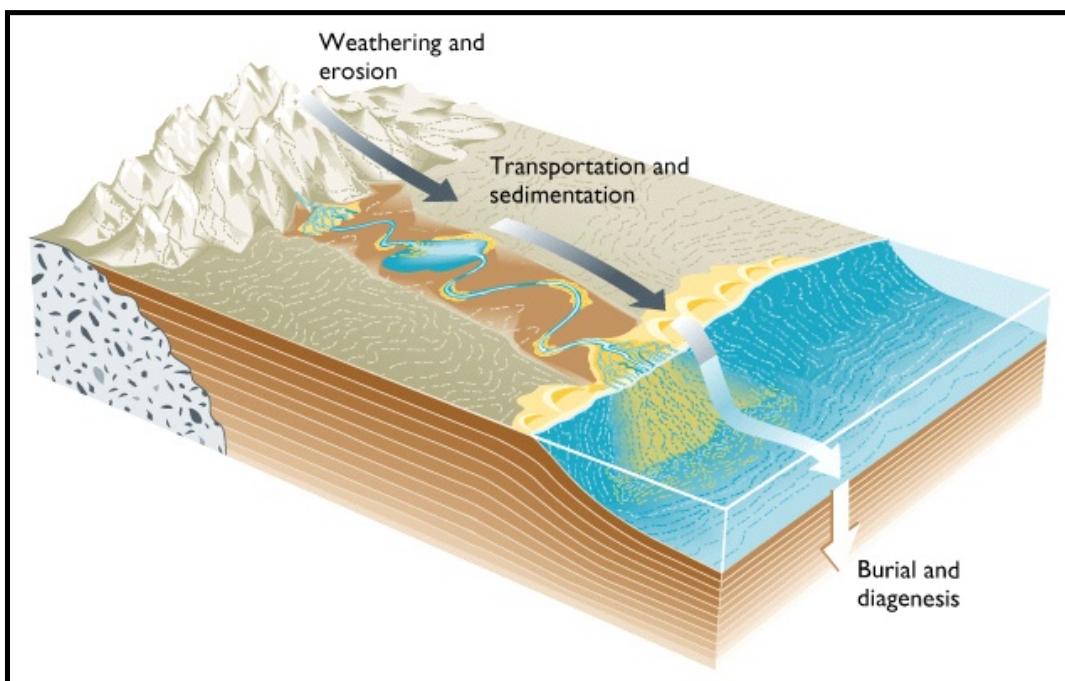
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## Example of Inverse Faulting



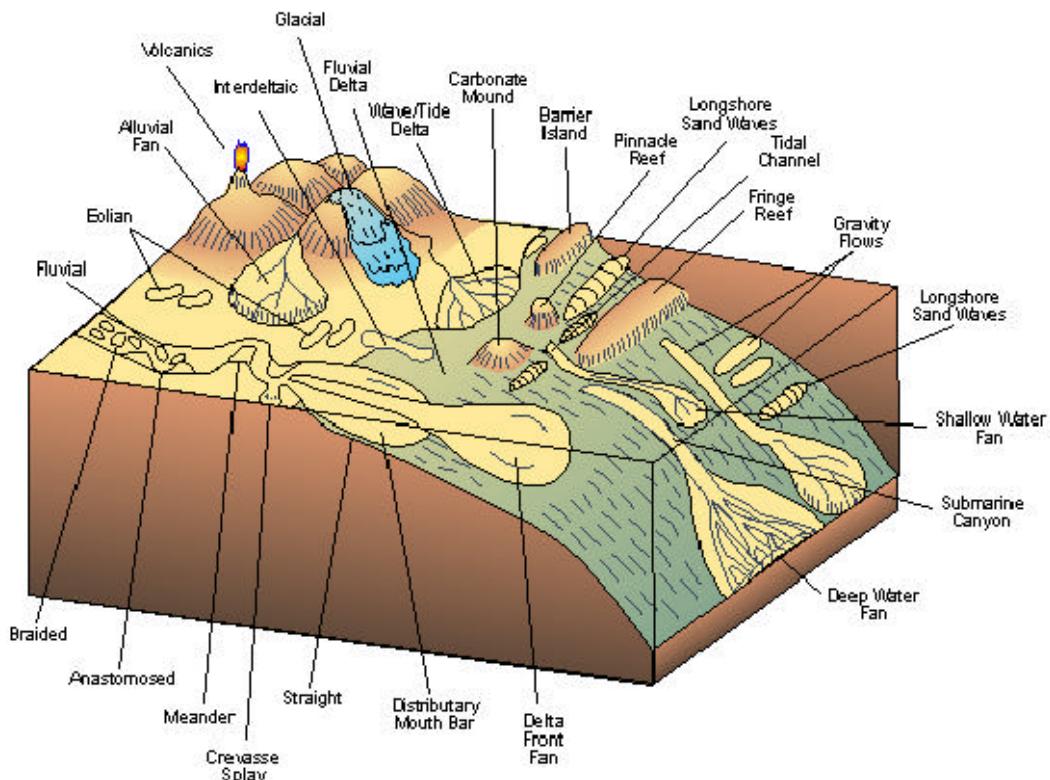
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## Weathering, Sediment Transport, Burial, and Diagenesis

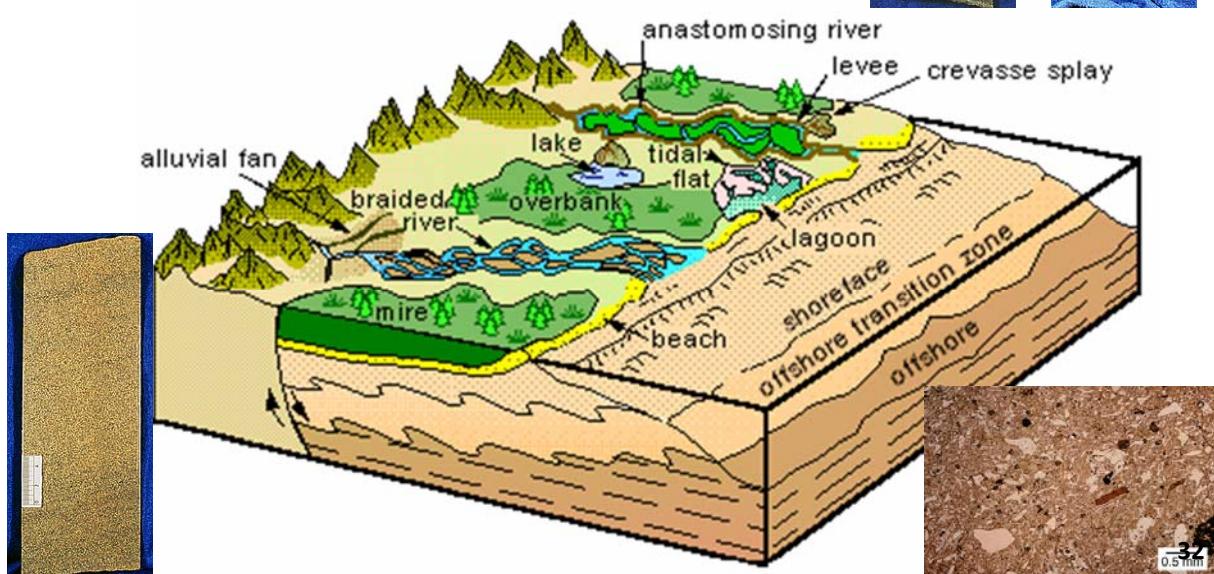
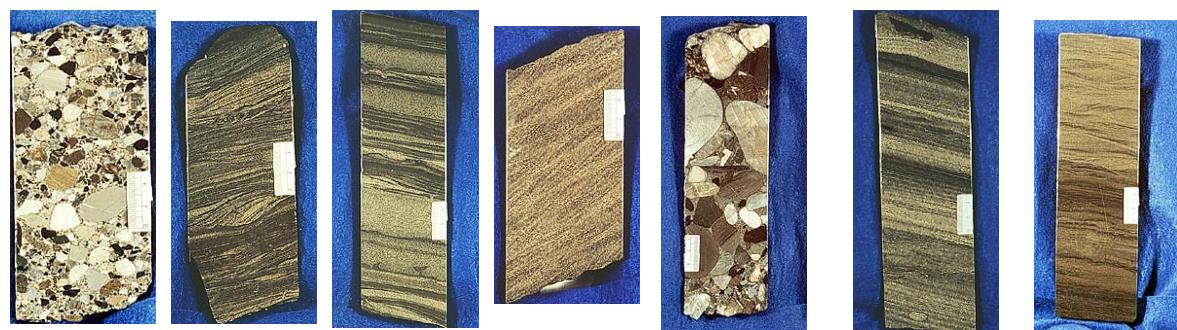


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# Sedimentary Environments



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## Fluvial Depositional Environments



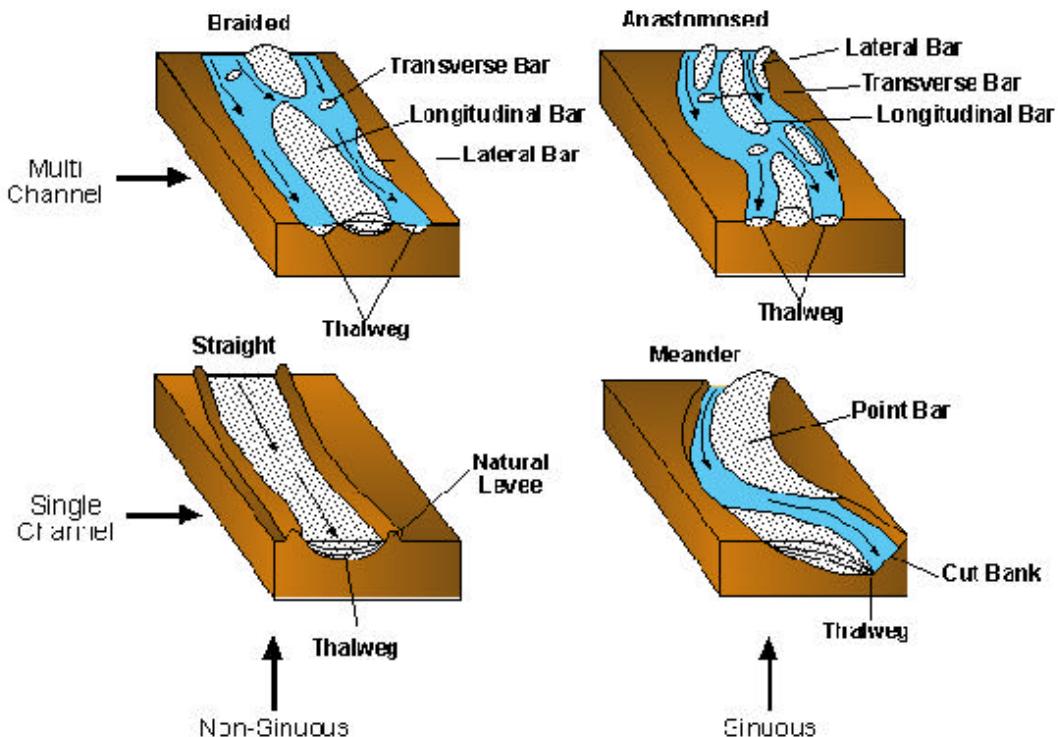
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## Entrenched Meander

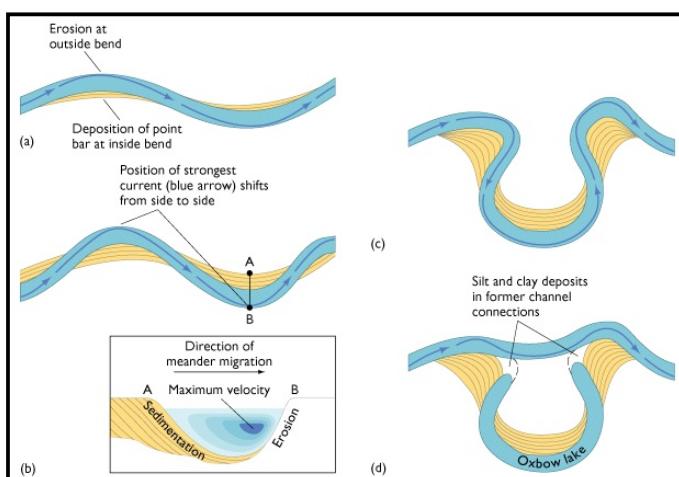


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# Fluvial Depositional Environments



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# Fluvial Depositional Environments

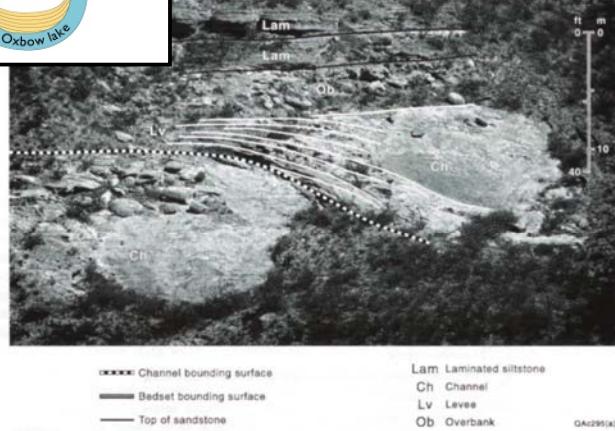
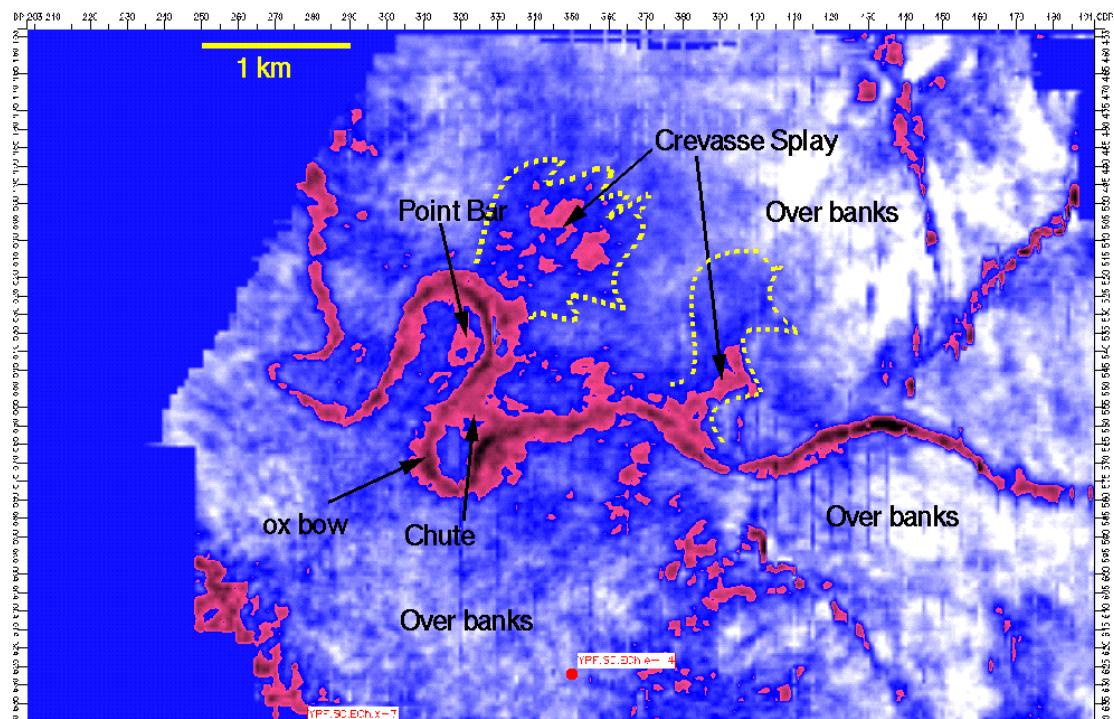


Figure 18. (a) Photograph of channel-levee deposits; (b) the same photograph with facies and surfaces labeled. The two channels are vertically stacked in an offset fashion.

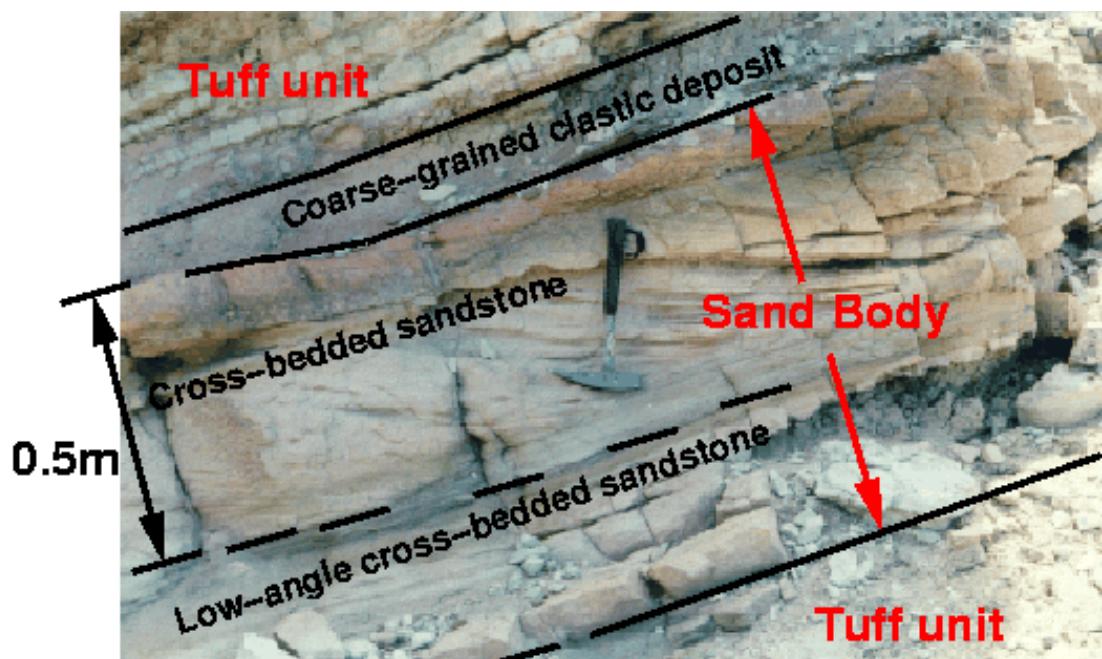
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## Example of a Fluvial Depositional Environment as Evidenced by Seismic Amplitude Data



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## Example of Fluvial Sands and Tuff Deposits The case of naturally radioactive sands



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Figure 18. (a) Photograph of channel-levee deposits; (b) the same photograph with facies and surfaces labeled. The two channels are vertically stacked in an offset fashion.

## Migrating Channel Forming "Stacked" Sands

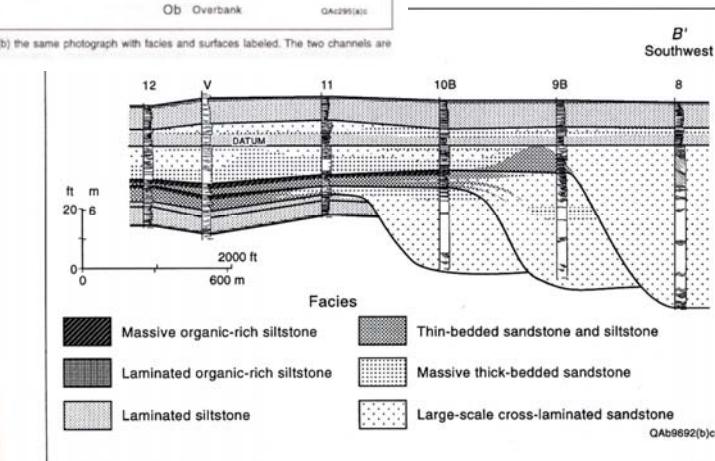


Figure 16. Cross section B-B' (see fig. 14 for location) showing distribution of facies and traces of key surfaces within a single high-order cycle, Bell Canyon Formation. Channels are amalgamated to form a composite body. The channels are stacked in an offset fashion.

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Fluvial/Lacustrine  
Eocene  
Wasatch Formation  
Canon Pintado, Colorado

Photo by Kevin Bohacs

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## Fluvial Depositional Environment



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## Braided Stream



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Photo by John Van Wagoner

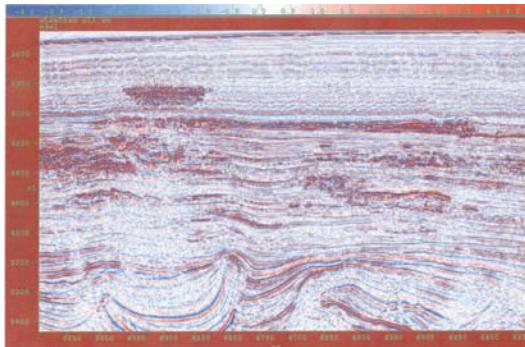
**Braided Stream  
Cretaceous  
Castlegate Sandstone Member of Price River Formation  
Castlegate, Utah**

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## **Modern Analogue: Meandering River**



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## Seismic Coherence



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## Alluvial Cycle = Graded Bedding



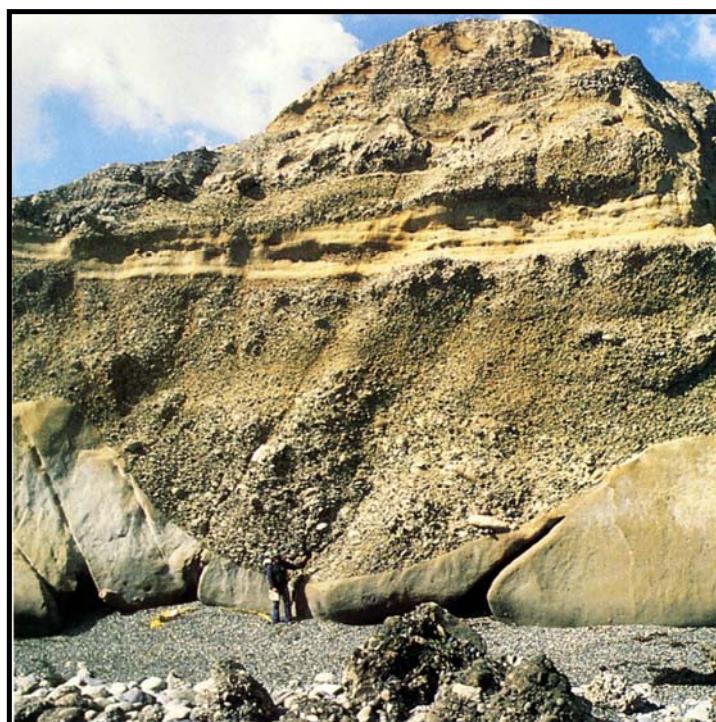
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## Alluvial Conglomerate Deposit



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## Example: Channel Cut and Fill



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## Example of Sedimentary Structures



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## Example of Terrigenous Sedimentary Environment



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## Example of Terrigenous Sedimentary Environment



51

## Example of Terrigenous Sedimentary Environment



52

## Example of Terrigenous Sedimentary Environment



53

## Example of Laminated Sands



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## Example of Stratigraphic Cross-Bedding



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## Example of Sedimentary Pinchout



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# Alluvial Fan



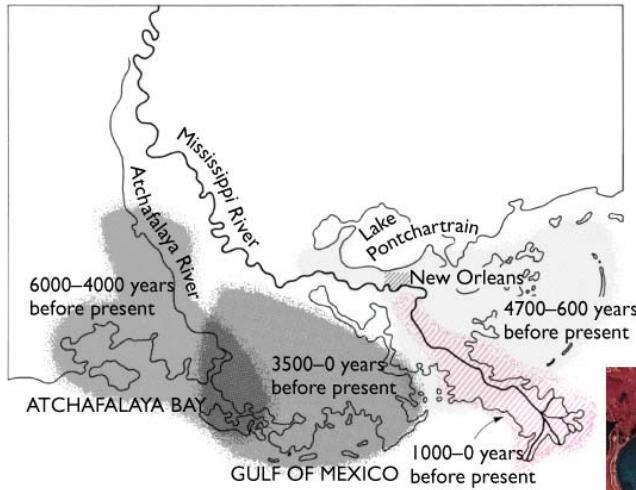
57



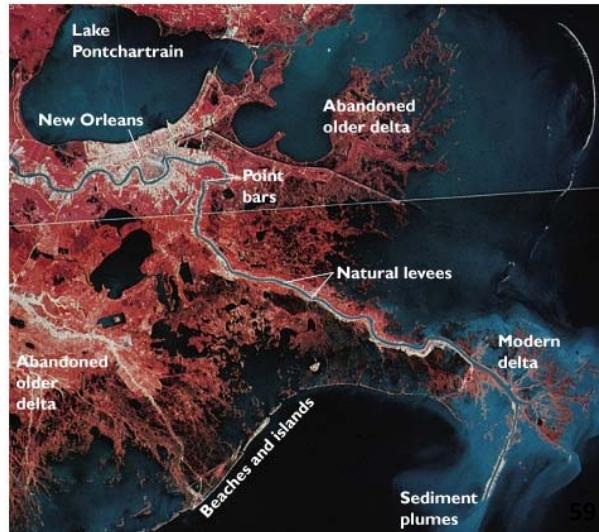
**Lake Floor Fan  
Cretaceous  
Candeias formation  
Itaparica Island, Bahia, Brazil**

Photo by Kevin Bohacs

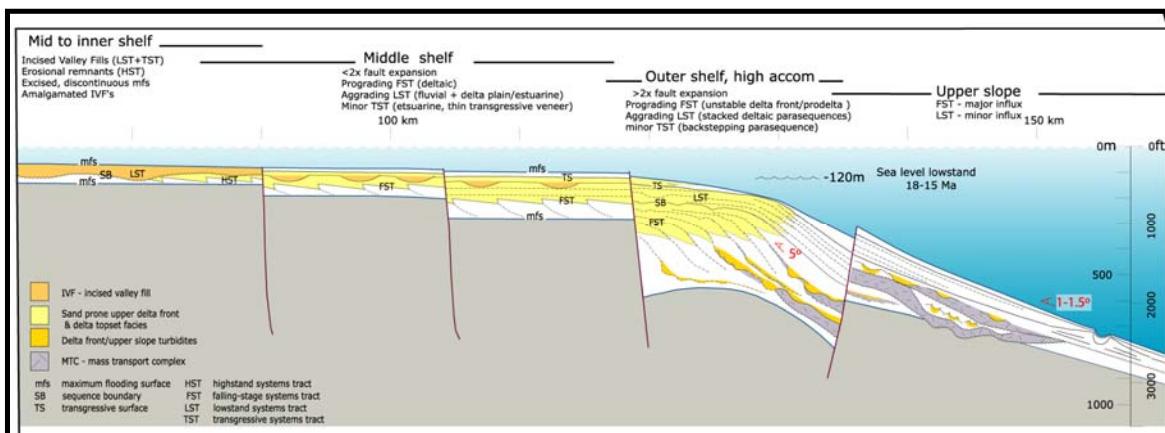
58



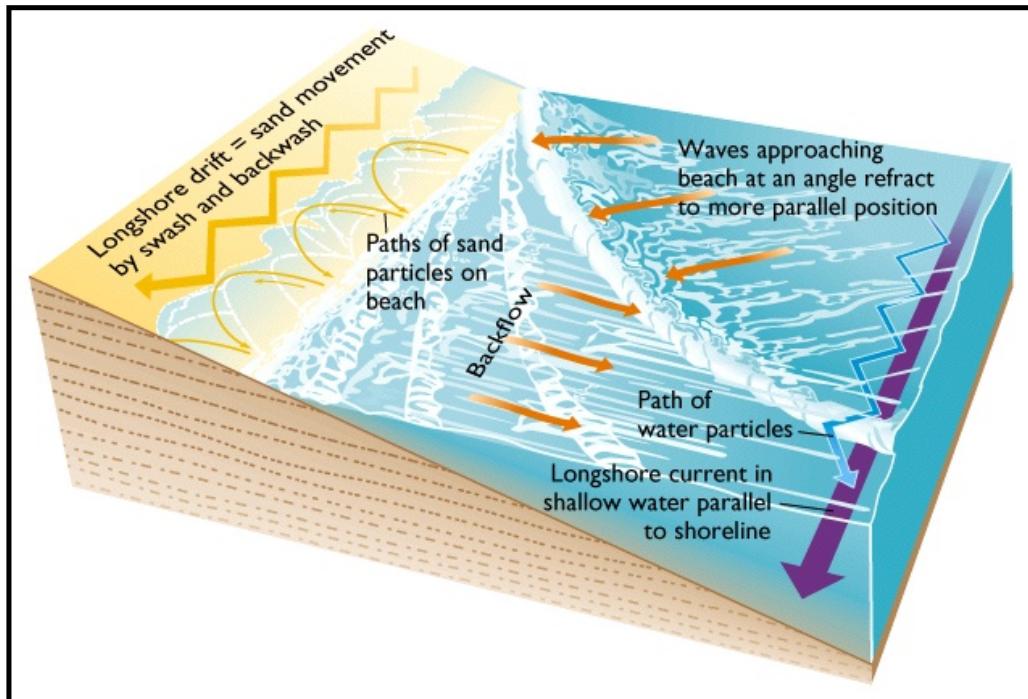
## Movement of channel and delta with time and deposition



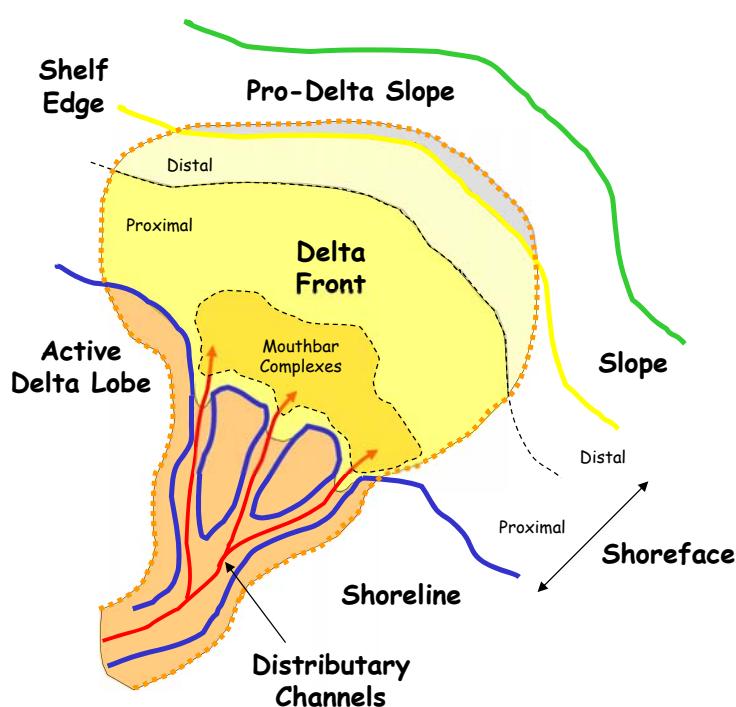
## Prograding Shelf-Edge Delta



# Along-Shore Transport



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## Delta Front or Shoreface Terminology

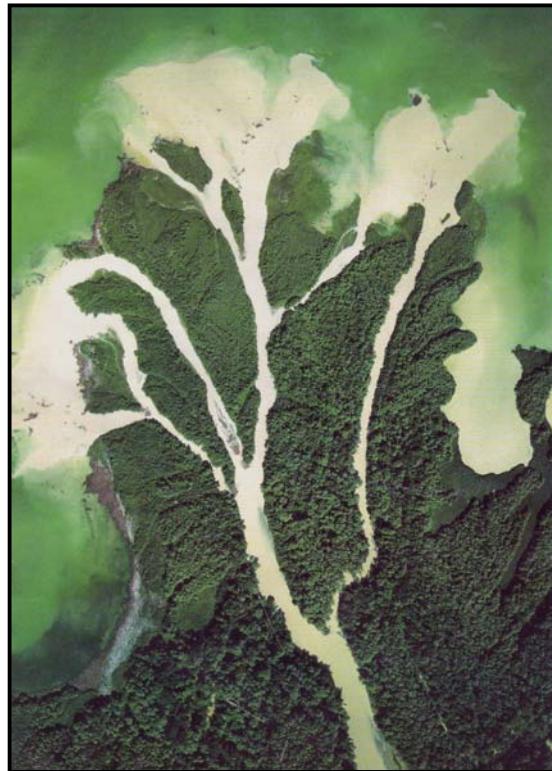
?Does it really matter to  
Sedimentology &  
Stratigraphy?

The answer is yes, delta  
front sediments reflect the  
interaction of Fluvial / Tidal  
/ Wave & Storm Processes  
and their associated  
environmental stresses.

Shoreface systems may also  
be affected by waves /  
storms, but are fully marine  
in character.

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## Contemporary Example

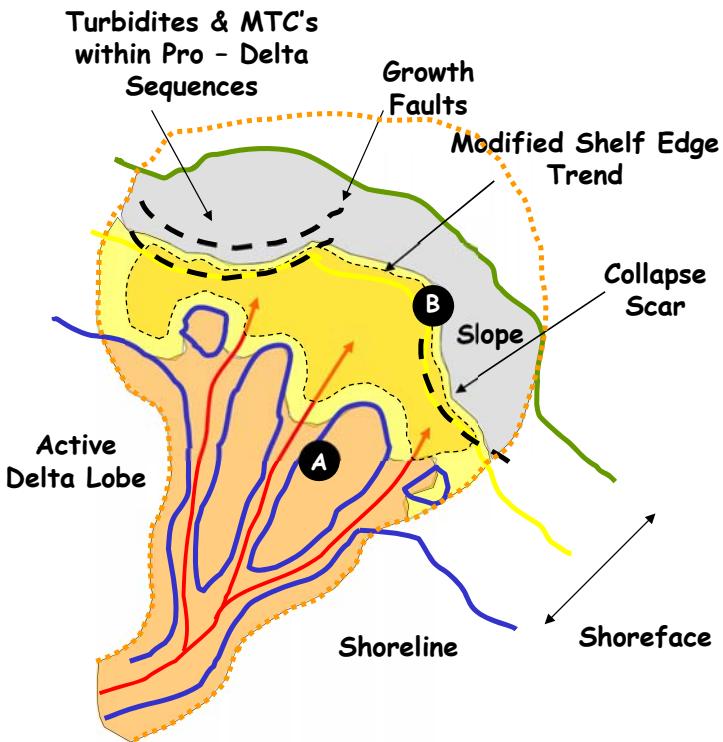


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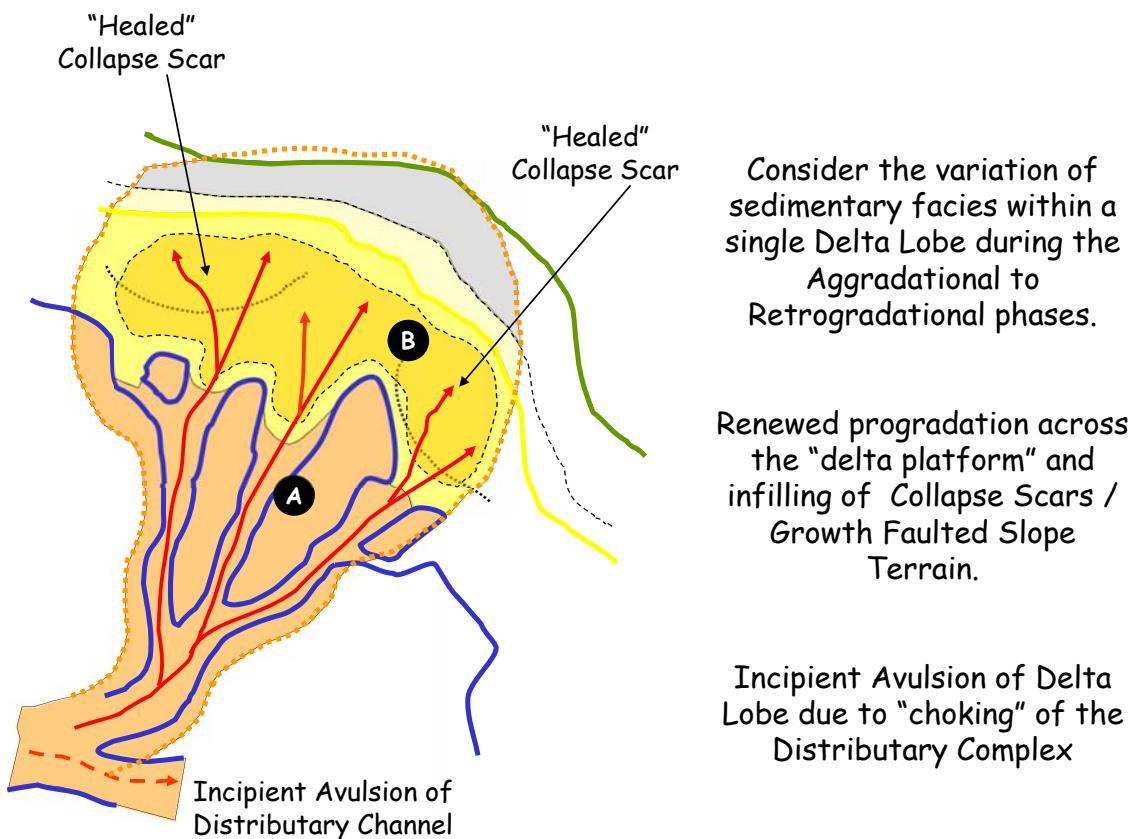
## Contemporary Example



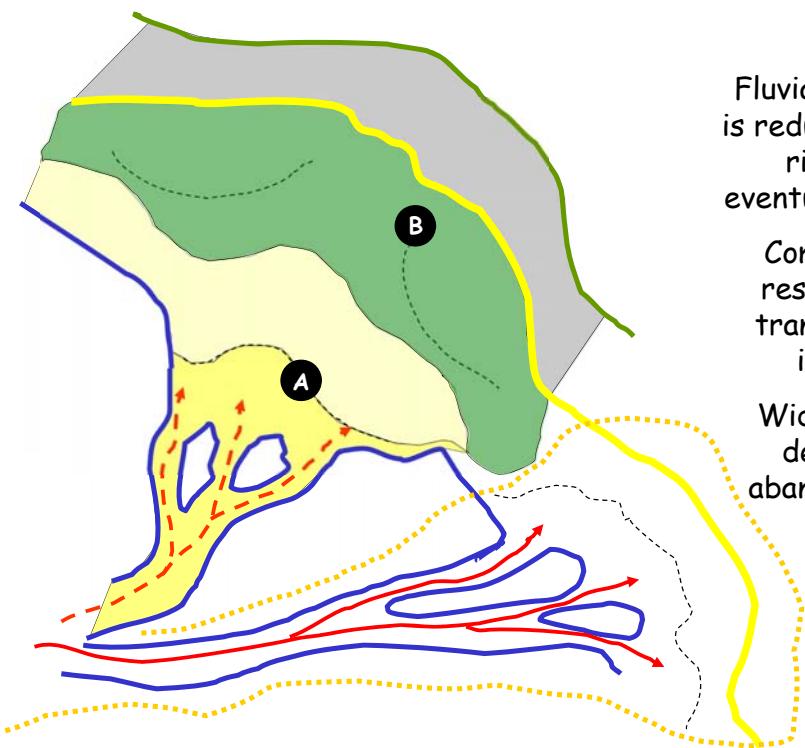
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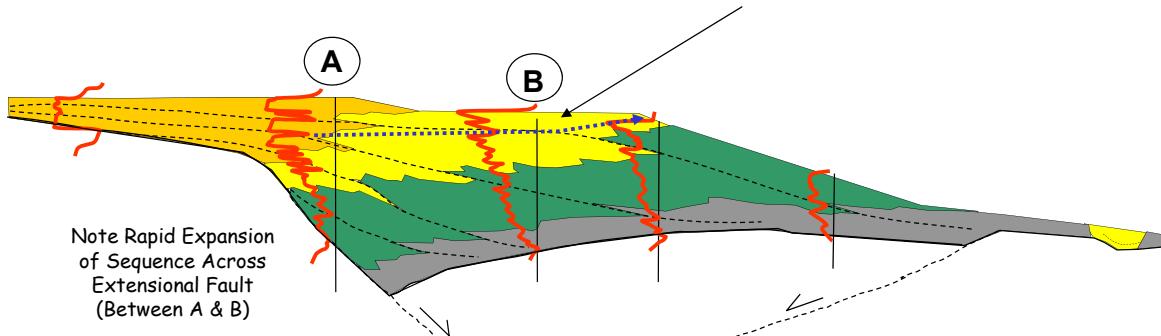


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### Progradational Phase : Sedimentation Rate Exceeds Subsidence Rate

Shelf - Edge Delta Builds Subaqueous Delta Platform by Progradation across previous Shelf - Edge

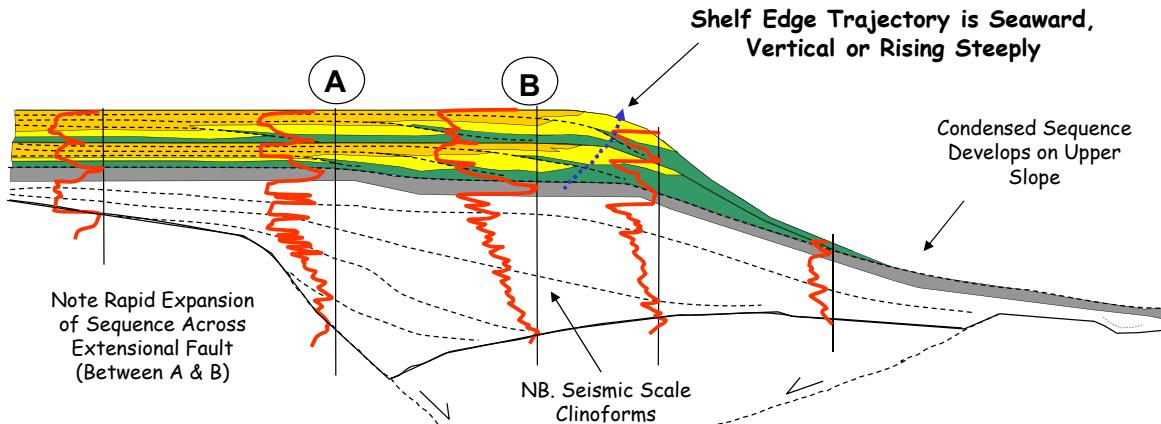
Shelf Edge Trajectory is Seaward, Flat or Rising Gently



68

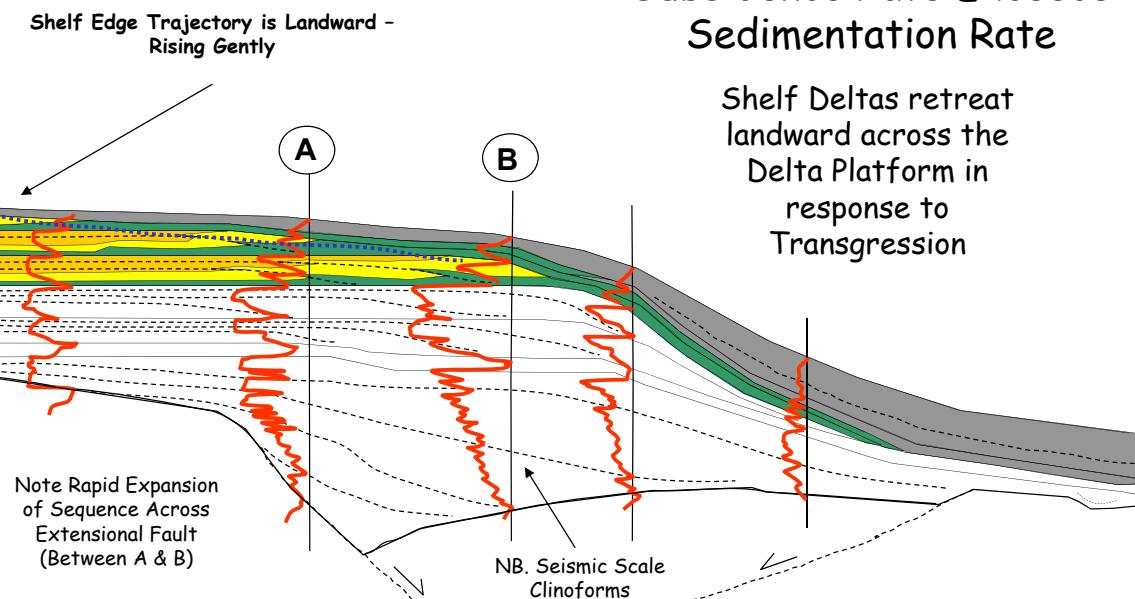
## Aggradational Phase : Sedimentation Rate Keeps Pace With Subsidence Rate

Shelf Deltas Aggrade on Subaqueous  
Delta Platform Built During Progradational  
Phase



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## Retrogradational Phase : Subsidence Rate Exceeds Sedimentation Rate



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**Tide Influenced Delta  
Frewins Castle Sandstone  
Belle Fourche Member  
Frontier Formation  
Cretaceous (Cenomanian)  
Tisdale Mountain Anticline, Wyoming**

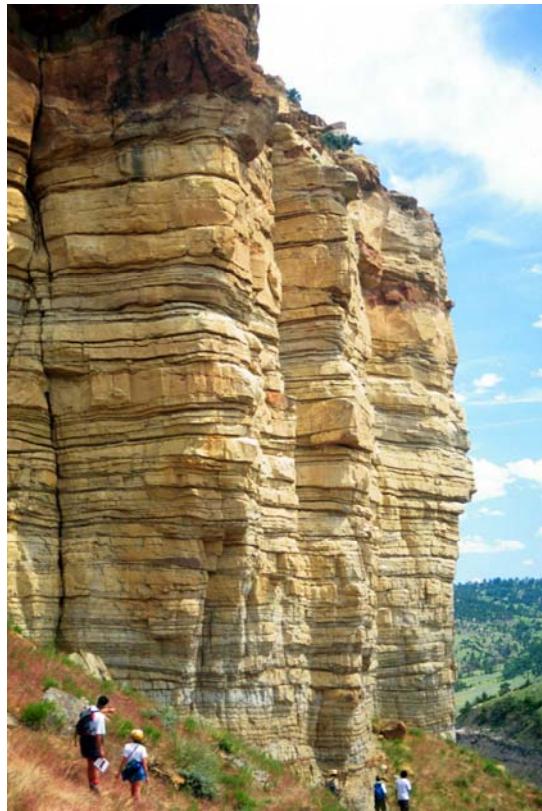


Photo by Rob Wellner 71

## Delta Front

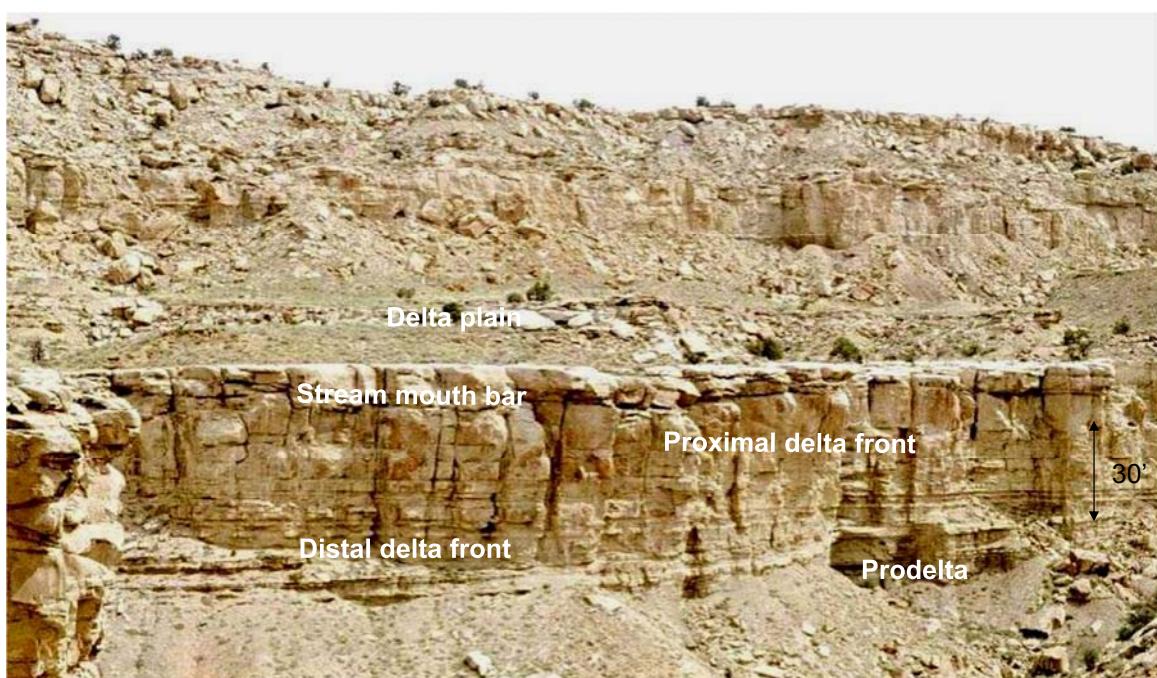


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## Delta Front



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**Delta Front and Stream Mouth Bar  
Cretaceous  
Ferron Formation  
Miller Canyon, Castle Valley, Utah**

Photo by Anthony Sprague

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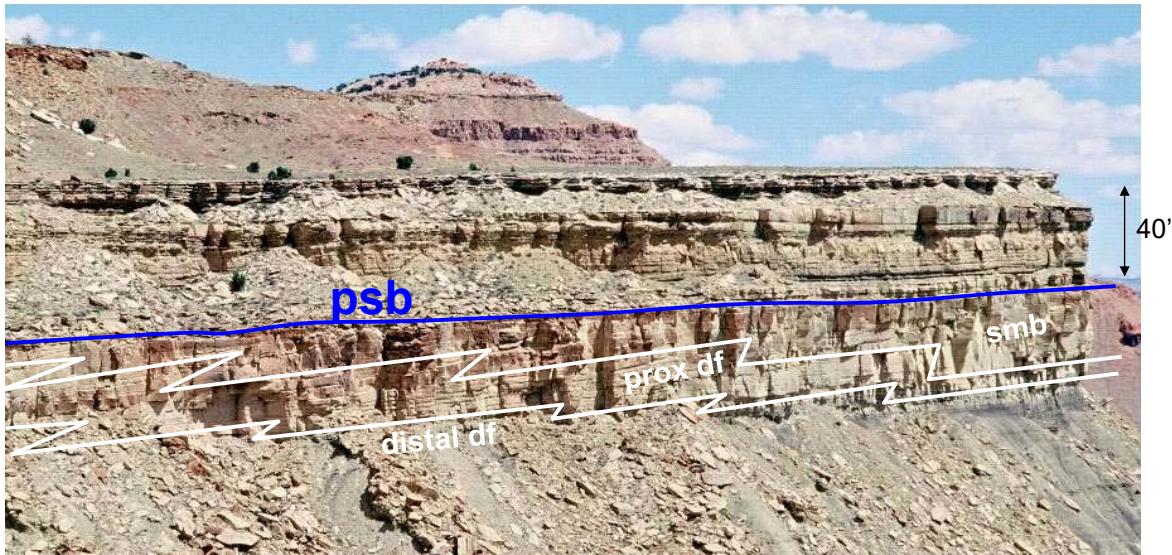


Photo by Anthony Sprague

**Delta Front and Stream Mouth Bar**  
**Cretaceous**  
**Ferron Formation**  
**Ivie Creek near I-70, Utah**

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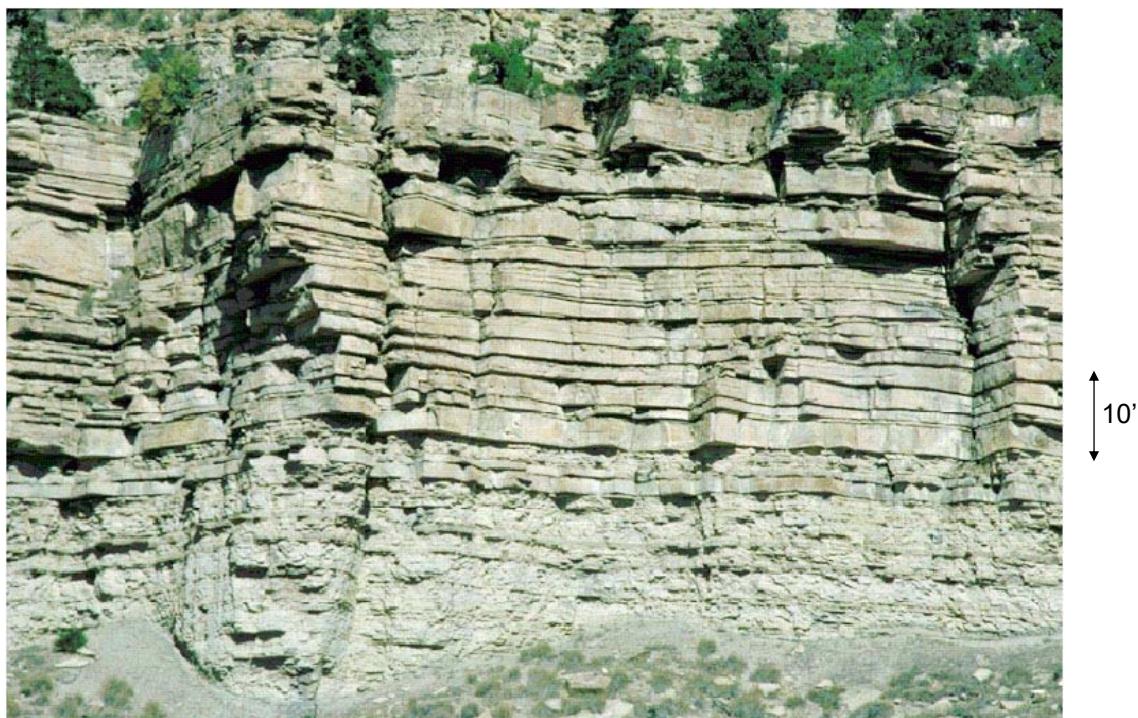
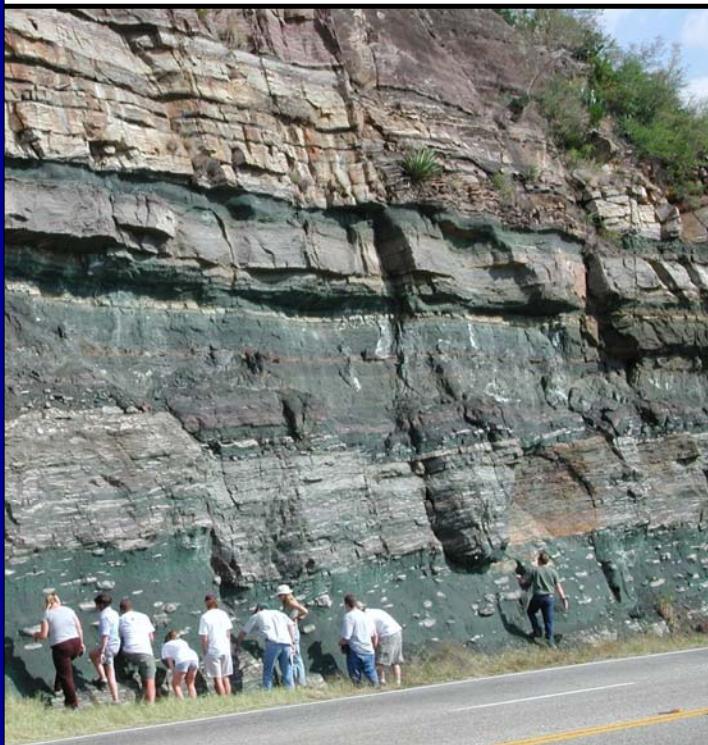


Photo by John Van Wagoner

**Delta Front**  
**Cretaceous**  
**Panther Tongue Member of Star Point Formation**  
**Hardscrabble Canyon, Utah**

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## Concretions



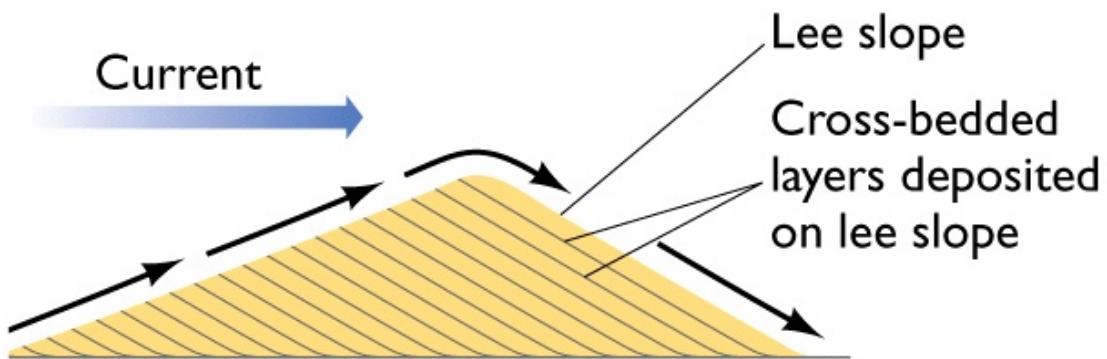
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## Stylolites



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## Example: Deposition of Aeolian Sands



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## Example: Modern Ripples



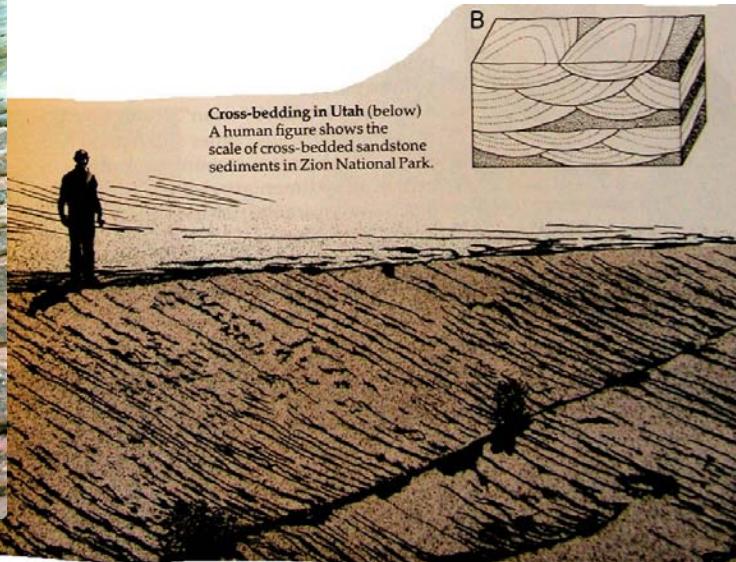
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## Example: Ancient Ripples



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## Wind-Blown Sediment (cross-bedding)



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## Example of Aeolian Cross-Bedding



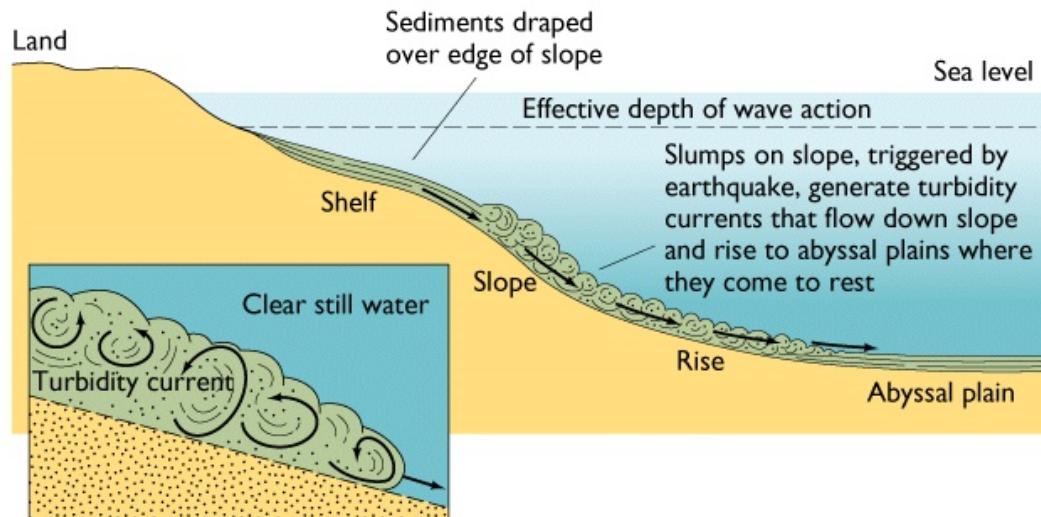
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## Example of Aeolian Cross-Bedding



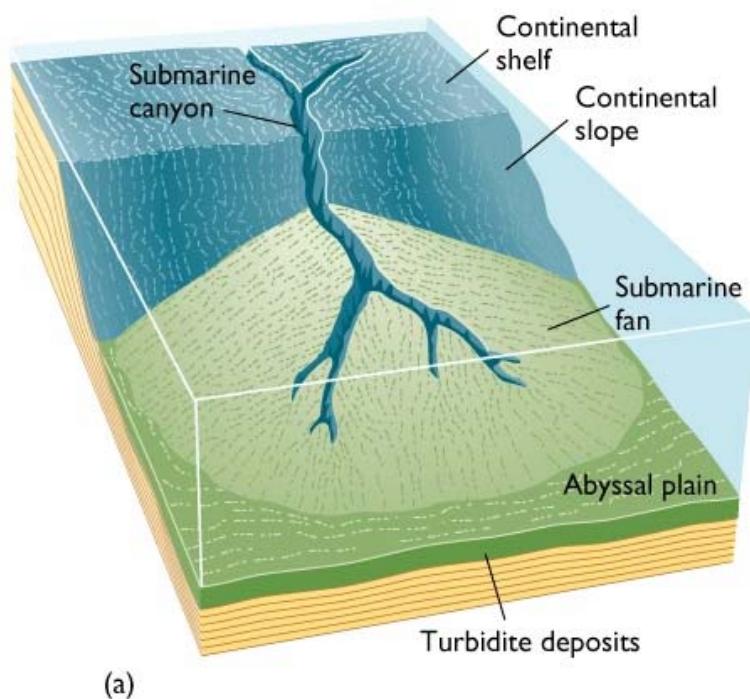
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# Turbidity Currents



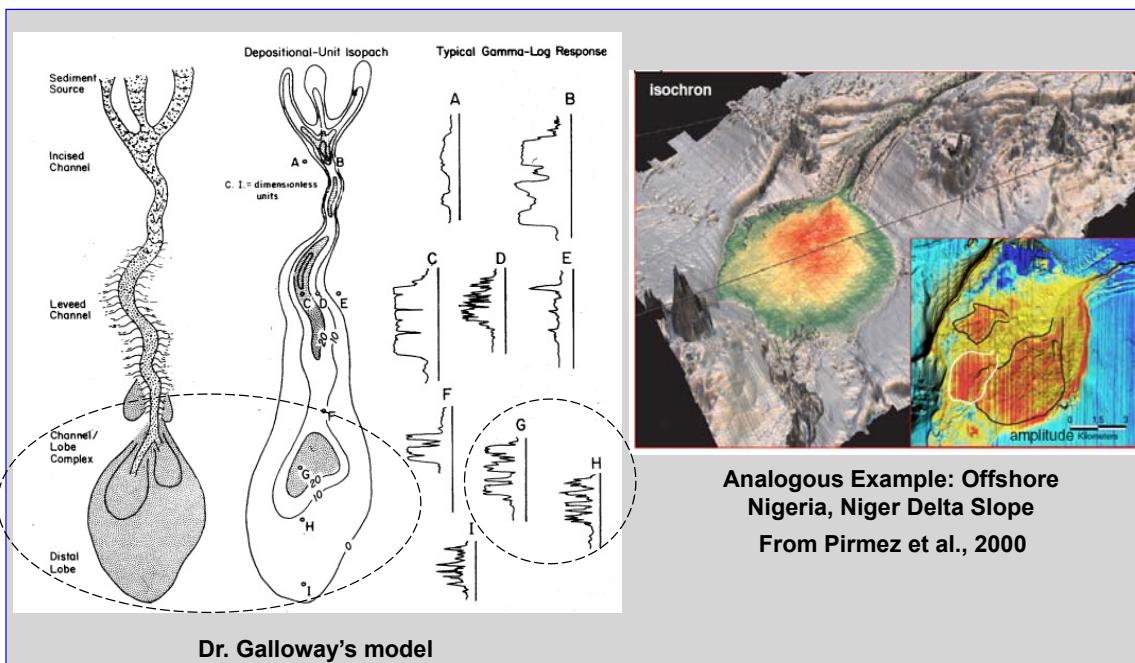
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## Turbidite Deposits / Submarine Fans

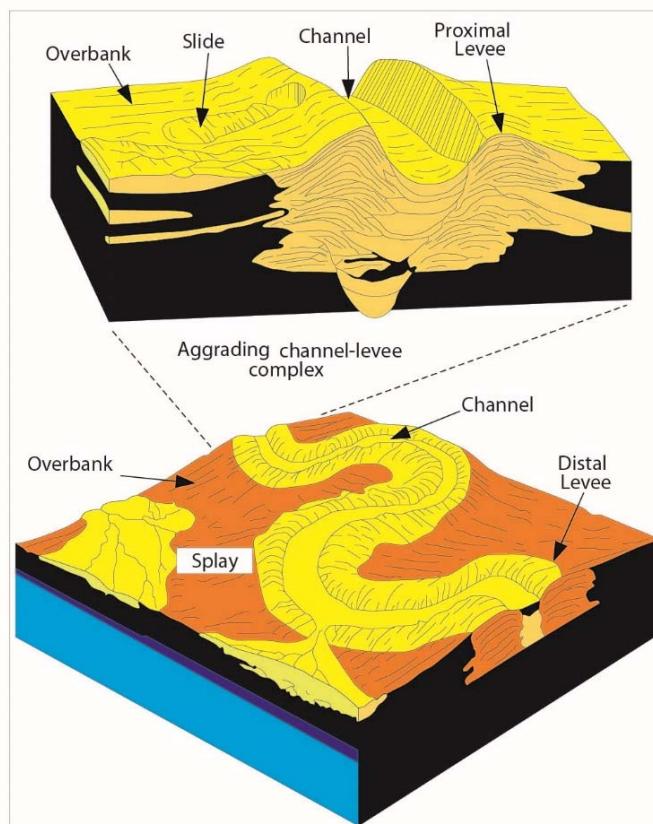


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# Geological/Depositional Model



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## Examples of Turbidites: Bouma Sequences



Thick-bedded turbidite sands



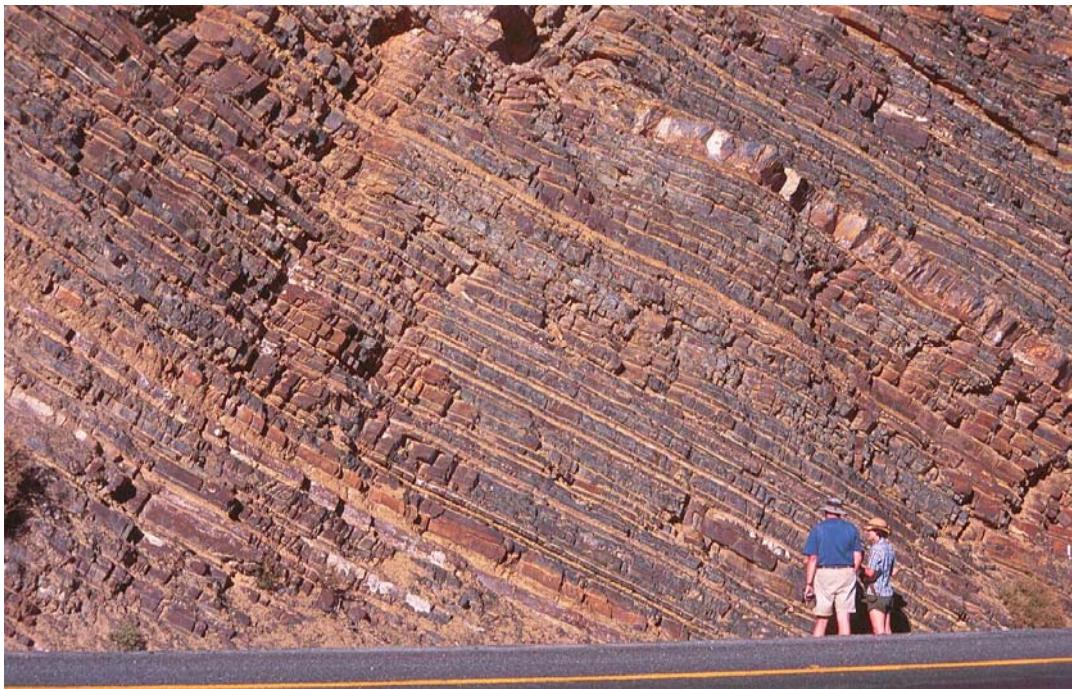
Thick-bedded turbidite sand with discontinuous shale-clast horizons

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## Example of Turbidite Deposition



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**Deepwater (Basinal Turbidites)  
Permian  
Collingham Formation  
Baviaans Syncline  
Laingsburg Karoo, South Africa**

Photo by Anthony Sprague

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**Deepwater  
Permian  
Brushy Canyon Fm  
Deleware Mountains, Texas**

Photo by Quinn Passey

92



**Deepwater (Basin Floor Turbidites)  
Carboniferous  
Ross Formation  
Kilcher Cliffs, Loophead Peninsula, Ireland**

Photo by Rob Wellner

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## Example of an Igneous Intrusion



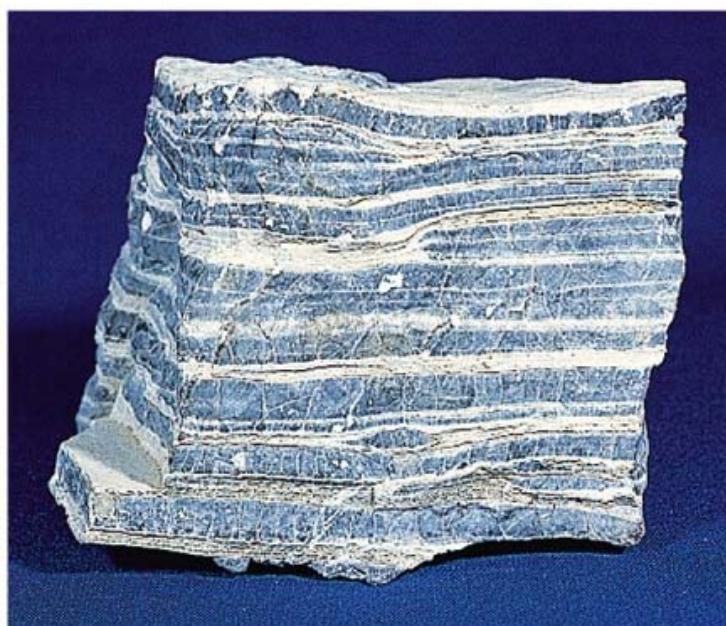
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# EXAMPLE OF TUFFS



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## Example of Carbonate Rock (Limestone)



(a)

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## Calcite Crystals



(c)

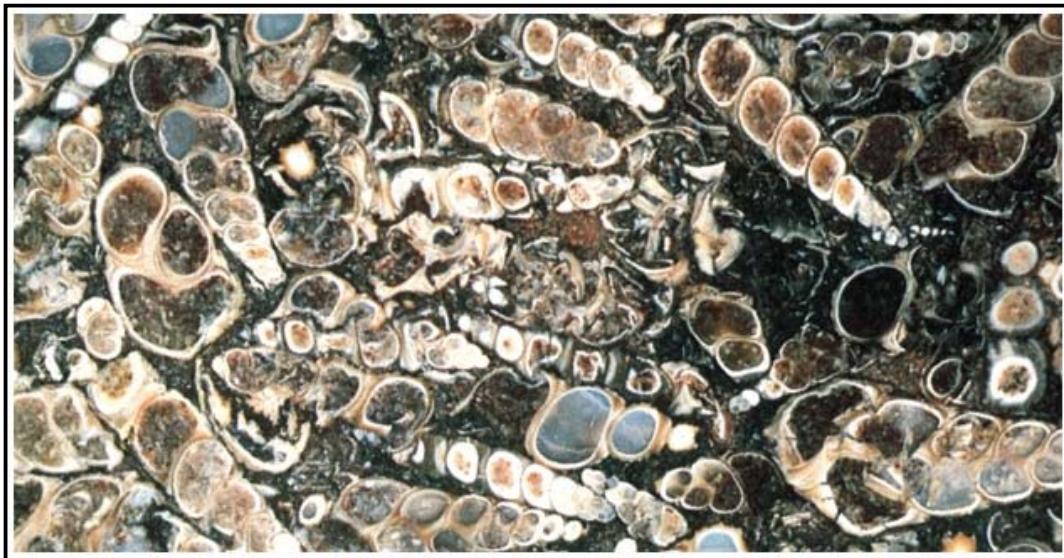
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## Differential Dissolution



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## Example of Fossilized Limestone



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## Structure, Bedding, and Texture in Carbonates



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## Structure, Bedding, and Texture in Carbonates



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## Example of Fractured Carbonates



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## Example of Shallow Marine Deposition



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## Example of Tectonically Deformed Carbonates



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## Example of Tectonically Deformed Carbonates



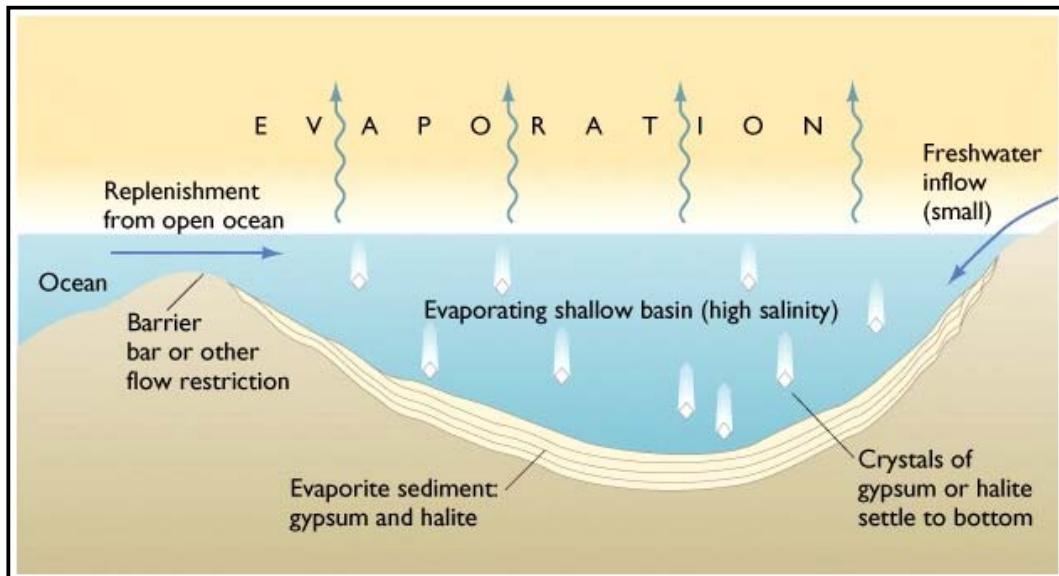
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## Example of Faulted Carbonates



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## Physical Origin of Evaporite Rocks (Salt, Halite, Anhydrite, Gypsum, etc.)



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## Example of Anhydrite Laminations



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