Outline Talk of Lec.5 Updated 5th Nov. 2023

1-Deltaic environment & definition.
2-Characterstics of the sandstones of deltaic environments.
3-Morphology of delta.
4-Delta Classification and sedimentation processes by Galloway,(1975).
5-Controlling facies delta environments.
6-Deltaic successions.
7-Fluvial-dominated delta.
8-Wave-dominated delta.
9-Tide-dominated delta.
10-River mouth Bar (delta).
11-Economic aspects of deltaic deposits.
12-References.

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Lec.5 Nov.20th 2023 Special Lecture
For Ph.D. Student,
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5-1Deltaic Environments

The marginal –marine setting lies along the boundary between the continental and marine depositional realms. It's a narrow zone dominated by river, wave, and tidal processes. The term delta, the Greek character Δ, was used to describe the mouth of the Nile river. Processes in model delta is, reduced to its simplest elements, a delta forms where a jet of sediment-laden water intrudes a body of standing water (Fig. 1). Current velocity diminishes radially from the jet mouth, depositing sediment whose settling velocities allow grain size to diminish radially from the jet mouth. Salinities may range in different parts of system from fresh through brackish to hypersaline water. (A) Radially decreasing current velocities from jet mouth deposit concentric arcs of sand, silt, and clay. (B) Delta progrades, forcing a channel through marginal levees. (C) Channel mouth chokes, levee ruptures, and a new delta builds out from the crevasse (Figure 1).

Three main morphological units appear. The delta platform is the subhorizontal surface nearest the jet mouth. It is basically composed of sand and is traversed by the distributary channel and its flanking levees. *A vertical section through the apex of a delta thus reveals a gradual vertical increase in grain size. At the base the prodelta clays grade up through delta slope silts into sands of the delta platform. Classically, these three elements have been termed the bottomset, foreset, and topset, respectively (Figure 2, 3).*

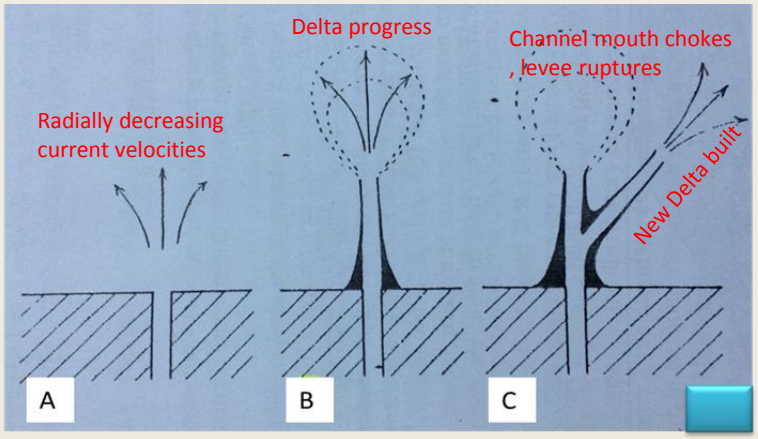


Figure 1: Stages development of an ideal delta system.

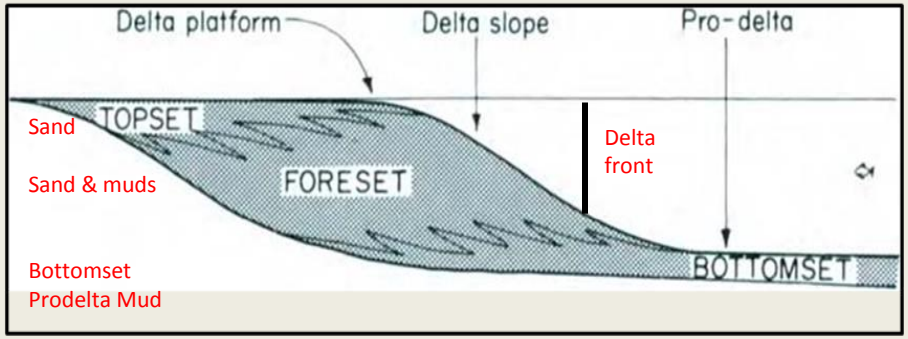


Figure 2: Terminology of a delta profile.

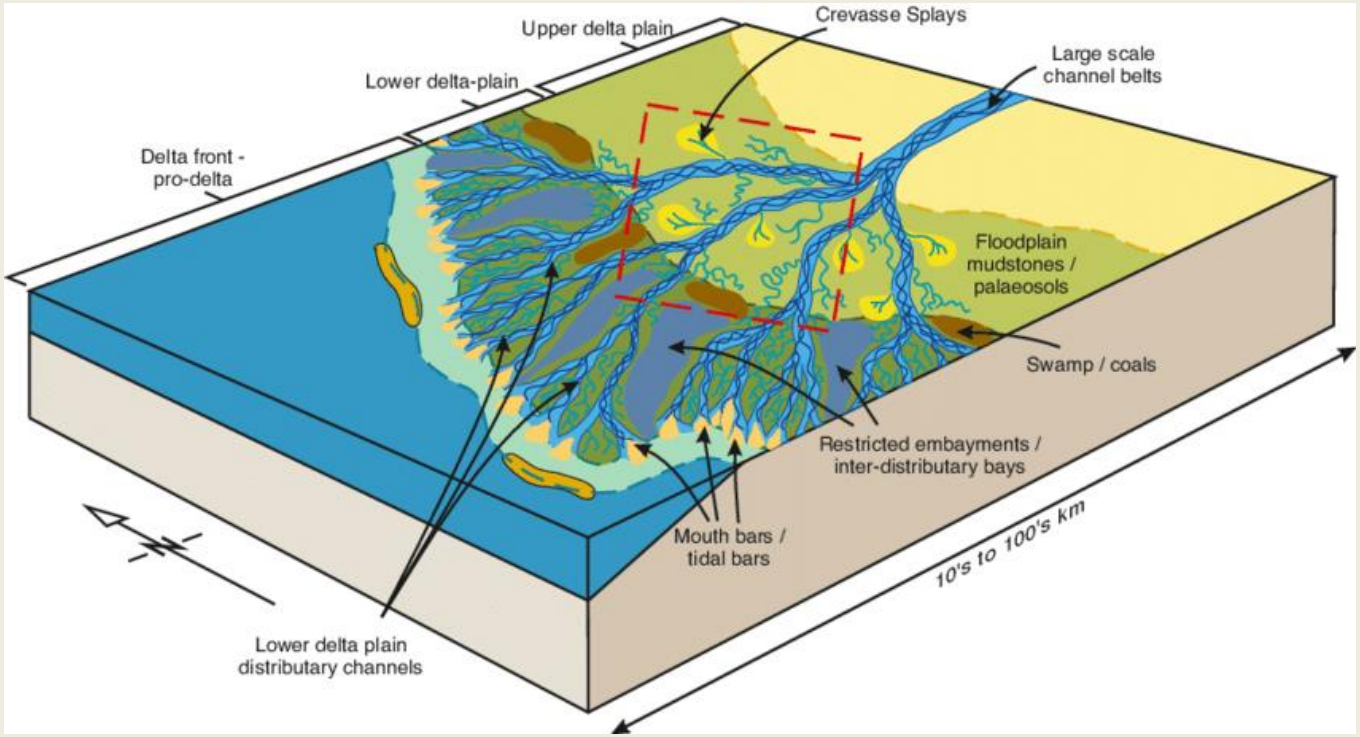


Figure 3: Subenvironments of deltaic .

5-2 Characteristics of deltaic deposits :-

1-Lithologies- conglomerate, sandstone and mudstone.

2-Mineralogy- variable delta front facies may be compositionally mature.

3- Texture –moderately mature in delta top sands and gravels, mature in wave reworked delta front deposits.

4-Bed geometry –lens shaped delta channels, mouth bar lenses variably elongate, prodelta deposits thin bedded.

5-Sedimentary structures-cross bedding and lamination in delta top and mouth bar facies.

6-Paelocurrent –topest facies indicate direction of progradation.

7-Fossils- association of terrestrial plants and animals of the delta top with marine fauna of the delta front.

8-Colour- not diagnostic, delta top deposits may be oxidized.

9-Sea progradation of the delta has thus generated an upward-coarsening sequence ranging from marine clays of the prodelta up into the delta-front sheet sands are repeated in many deltaic environments.

-Factors that controlling delta formation:-

1-Climatic conditions.

2-Geologic setting.

3-Sediment sources in the drainage basin.

4-Tectonic stability.

5-River slope and flooding characteristics.

6-Intensities of depositional and erosional processes.

7-Tidal range and offshore energy conditions.

5-3 Morphology of Delta

A delta is divided into three major morphological subdivisions,

1-The delta plain: The terrestrial environment where river meets ocean. It differs from fluvial floodplains and channels because it develops on top of previous deltaic deposits. In it, we see: distributary channels / flood plains / inter-distributary marshes and swamps / beach complexes. Most of delta plains are affected by fluvial or tidal processes and rarely by waves (Figure 4).

2-Delta front is interaction zone between fluvial and basinal processes, *Characterized by: thinly bedded turbidites / slumps, slides and convolute bedding / grain size grades from sand and silt near sea level to fine clay farther out. The delta front environment is an extremely sensitive environment. It is strongly affected by waves, tides, changing sea level.*

3-Prodelta *is located in the subtidal to deep continental shelf environment. It contains mainly fine grained distal mudstones usually finely laminated.*

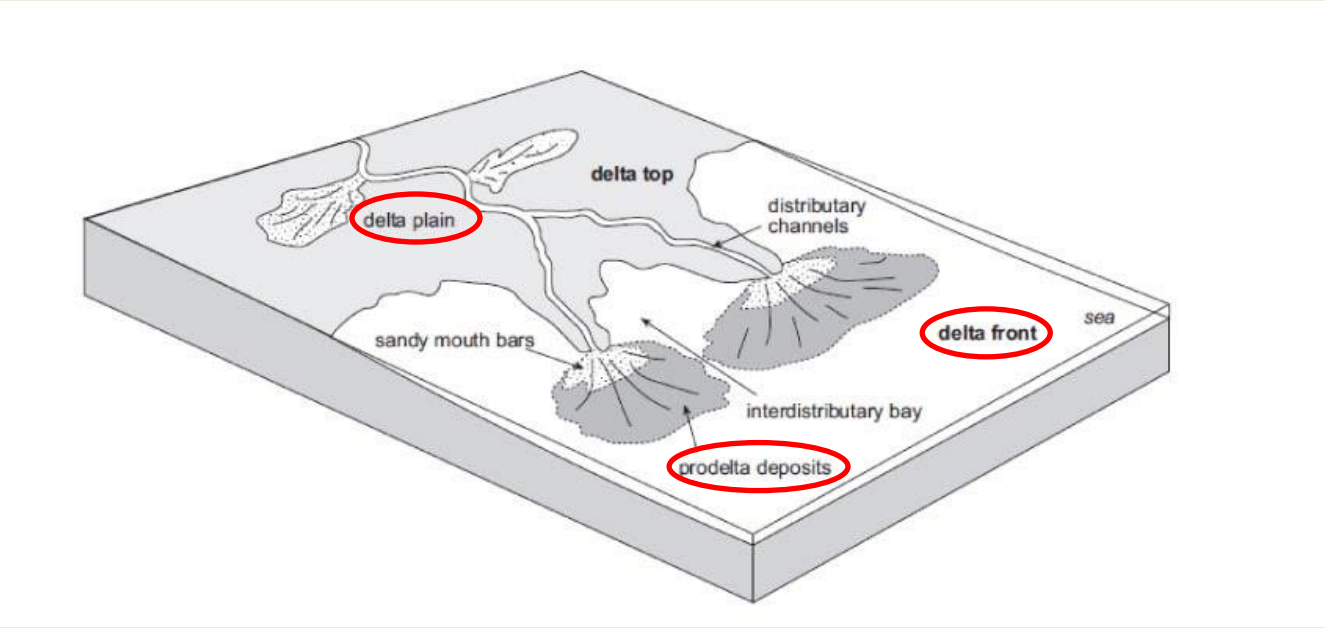


Figure 4 : Morphological subdivision of a typical delta (after Nichols, 1999)

5-4 Delta Classification and sedimentation processes

The distribution and characteristics of delta are controlled by a complex set of interrelated fluvial and marine/lacustrine processes and environmental conditions. Theses factors include *climate, water and sediment discharge, river mouth processes, nearshore wave power , tides, nearshore currents and winds* (Coleman,1981).

Deltas can be classified in several ways (Nemec,1991);however, classification on the basis of delta front regime(Galloway,1975) appears to be favored by many geologists. Deltas are classified thus as *(1) Fluvial –dominated , (2) Tide –dominated, (3) Wave –dominated* (Figure 5). Each of theses kinds of deltas can be further distinguished on the basis dominant grain size of sediments , that is *mud/silt, fine sand, gravelly sand, or gravel.*

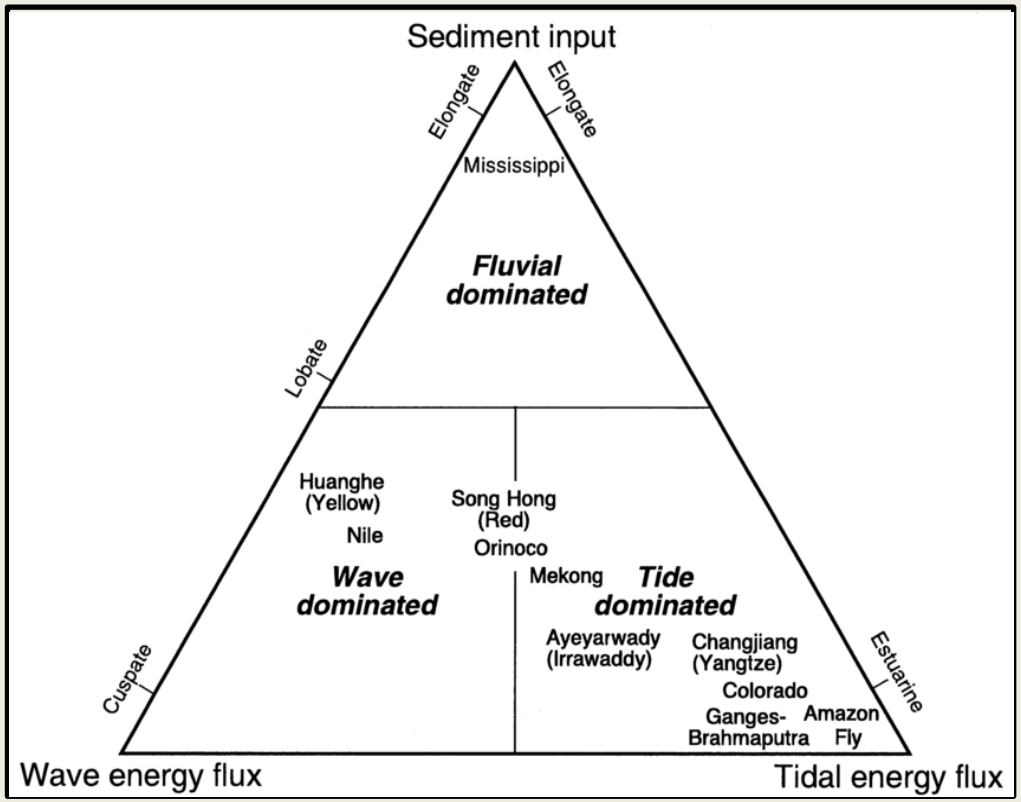


Figure 5: Classification of deltas on the basis of dominant process dispersal at the delta front, and prevailing grain size of sediment delivered to the front. (Galloway, 1975).

*Delta now commonly classified in terms of the dominant grain size of the deposits and the relative importance of **fluvial , wave and tide** processes (After Orton and Reading , 1993). Figure 6 . This scheme can be applied to modern and ancient deltas which are interpreted as a delta facies.*

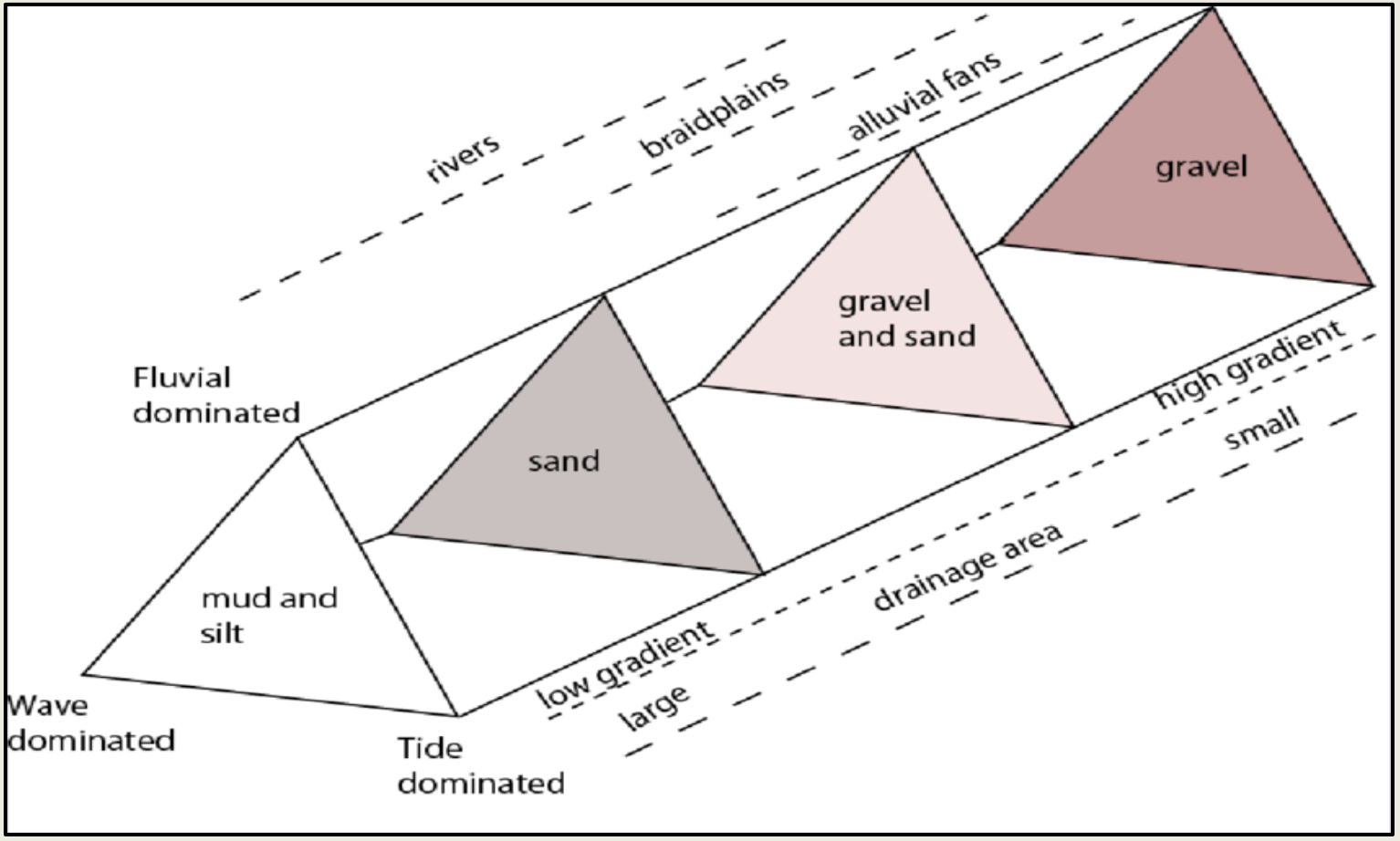


Figure 6: Classification of Delta taking grain size and sediment supply mechanisms (After Orton and Reading 1993).

5-5 Controlling facies delta environments

*The relationships between the controls , the form of the delta and facies are summarized in the figure 7 showing three main controls **Climate**, **tectonic** and **eustatic sea level** . The supply of the sediment is determined by the nature of the hinterland, with the climate influencing the weathering and erosion processes and the discharge, the amount of water in river, while there are tectonic controls on the topography, especially the gradient of the river and the effect this has on the grain size of the material carried.*

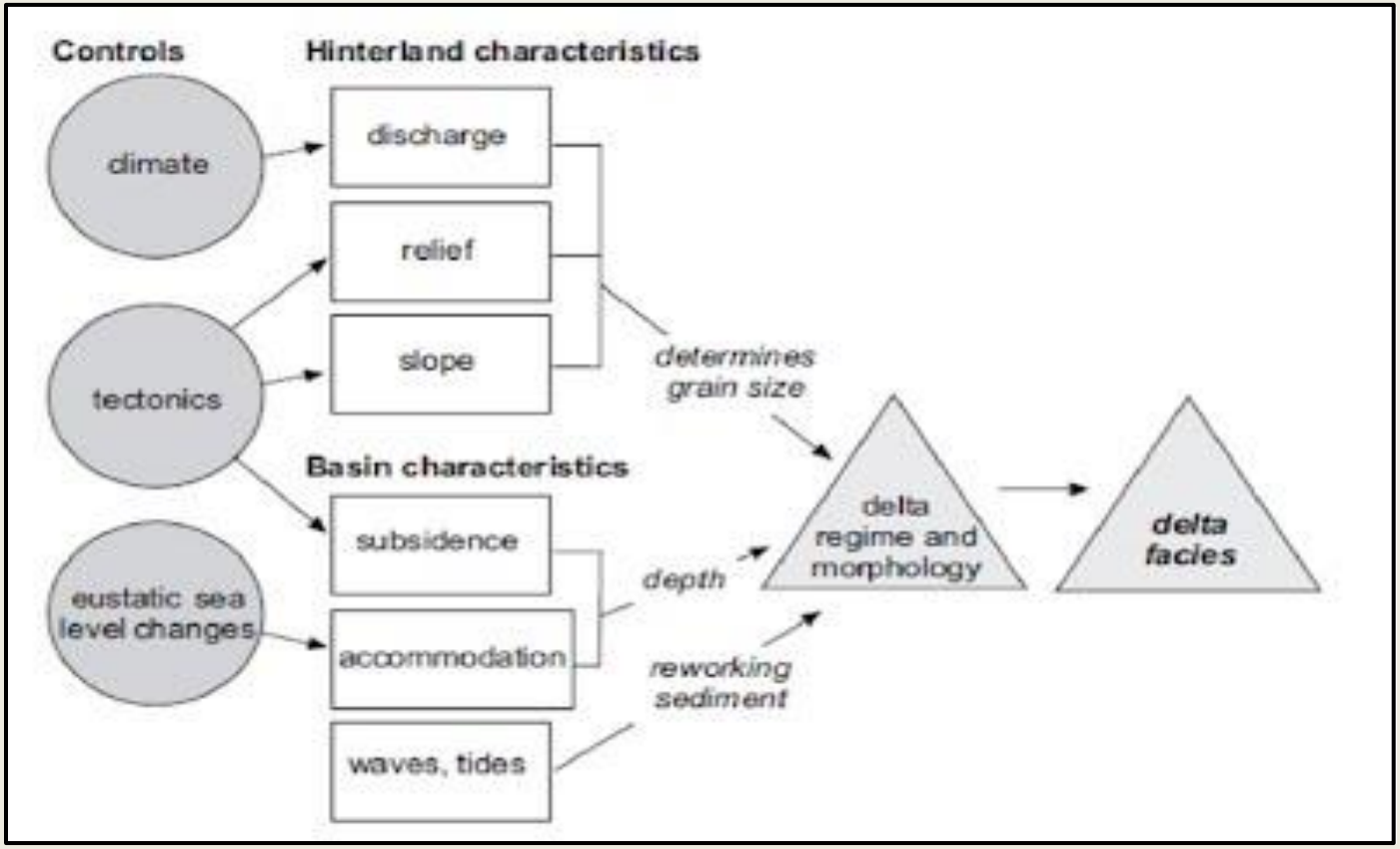


Figure 7 : Philosophy of Controls on delta environments and facies. (Adapted from Elliott,1986.)Facies Models

5-6 Deltaic successions

The definition of delta includes the concept of **progradation,** that the deposition results in the sediment body building out into the lake or sea, *furthermore sediment supply > than accommodation space*. The sedimentary succession formed will therefore consist of progressively shallower facies as the prodelta is overlain by the delta front, which is in turn superposed by mouth –bar and delta top sediments. *The succession formed by progradation of a delta has a shallowing –up pattern* (Figure 8).

-*In the delta-front subenvironments the deepest water facies, the prodelta deposits, are the finest grained as they are deposited in the high energy setting*. In the *shalllowing-up succession they will be overlain by sediment of delta slope, which will tend to be little coarser and the shallowing facies will be those of mouth bar which are typically sandy or even gravelly sediment.* The beds formed progradation and show coarsening-up ward successions.

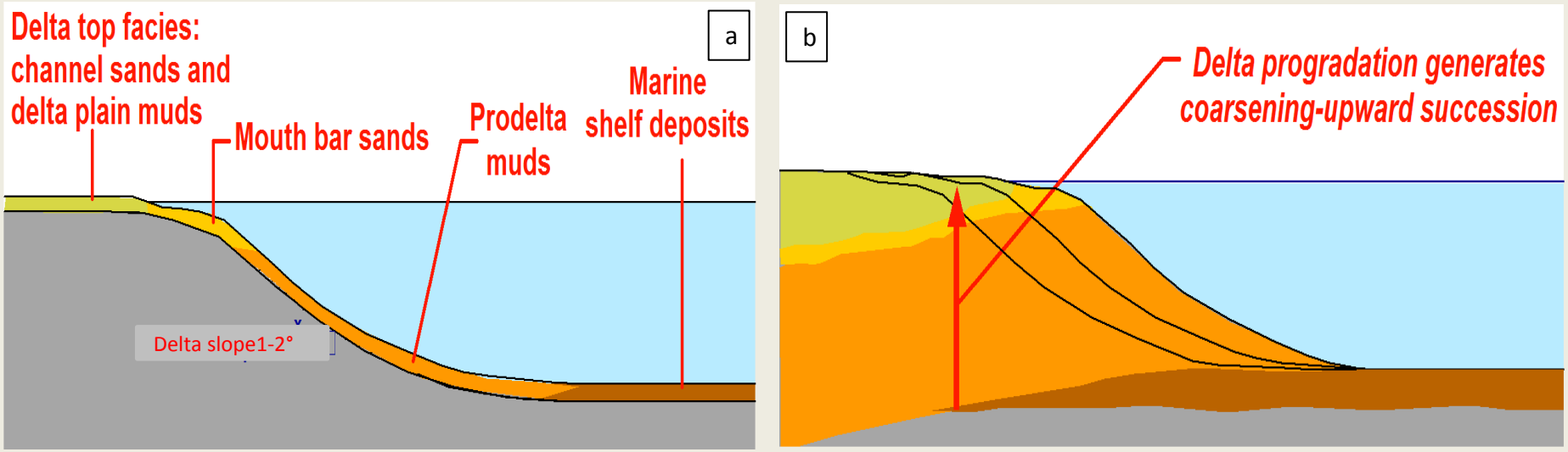


Figure 8 : A cross-section a cross a delta lobe: progradation results in a coarsening up succession.

Different in the grain size of sediment supply affect the form of a delta,
(1)High proportion of suspended load results in relatively small mouth bar (Figure 9a), (2)high proportion of bedload results in delta with high proportion of mouth bar gravels and sands (Figure 9b).

5-7 Fluvial-dominated delta

A delta are regarded as river-dominated where the effects of tides and waves are minor so the form of the delta is largely controlled by fluvial processes of transport and sedimentation. The unidirectional fluvial current at the mouth of the river continues into the lake or sea. *Fluvial-dominated delta plain associations comprises large scale of fluvial-distributary channel, small-scale crevasse channel, and facies of small-scale coarsening-upwards sequences reflecting a repeated infilling of the bays (Horne and Ferm , 1975), theses sequence on average 4-10 m thick sequence (Figure 10). Plant debris are abundant. Paleocurrents are mostly directed offshore and are best measured from trough-cross bedding of delta mouth bar and channel*. Most of the ancient delta-front sequences are mud-silt-sand systems deposited at the margin of marine sedimentary basins.

-Bates (1953) contrasted the behavior of sediment river water as it enters equally dense, more dense, and less dense basin water. However, The discharge of river water and sediment into a lake or ocean is refereed to as a jet. Bates (1953) states three hypothesis of river water entering water basin (sea) (Figure 11).

1-Hypopycnal: *If river outflow is less dense than basin water it flows outward on top of the basin water horizontally oriented plane jet (Figure 11a).*

2-Homopycnal flow: *River water entering water basin of equal density (Figure 11b).*

3-Hyperpycnal flow: *River water has higher density than basin water flows beneath the basin water, commonly during floods, generating a vertically oriented plane jet (Figure 11c).*

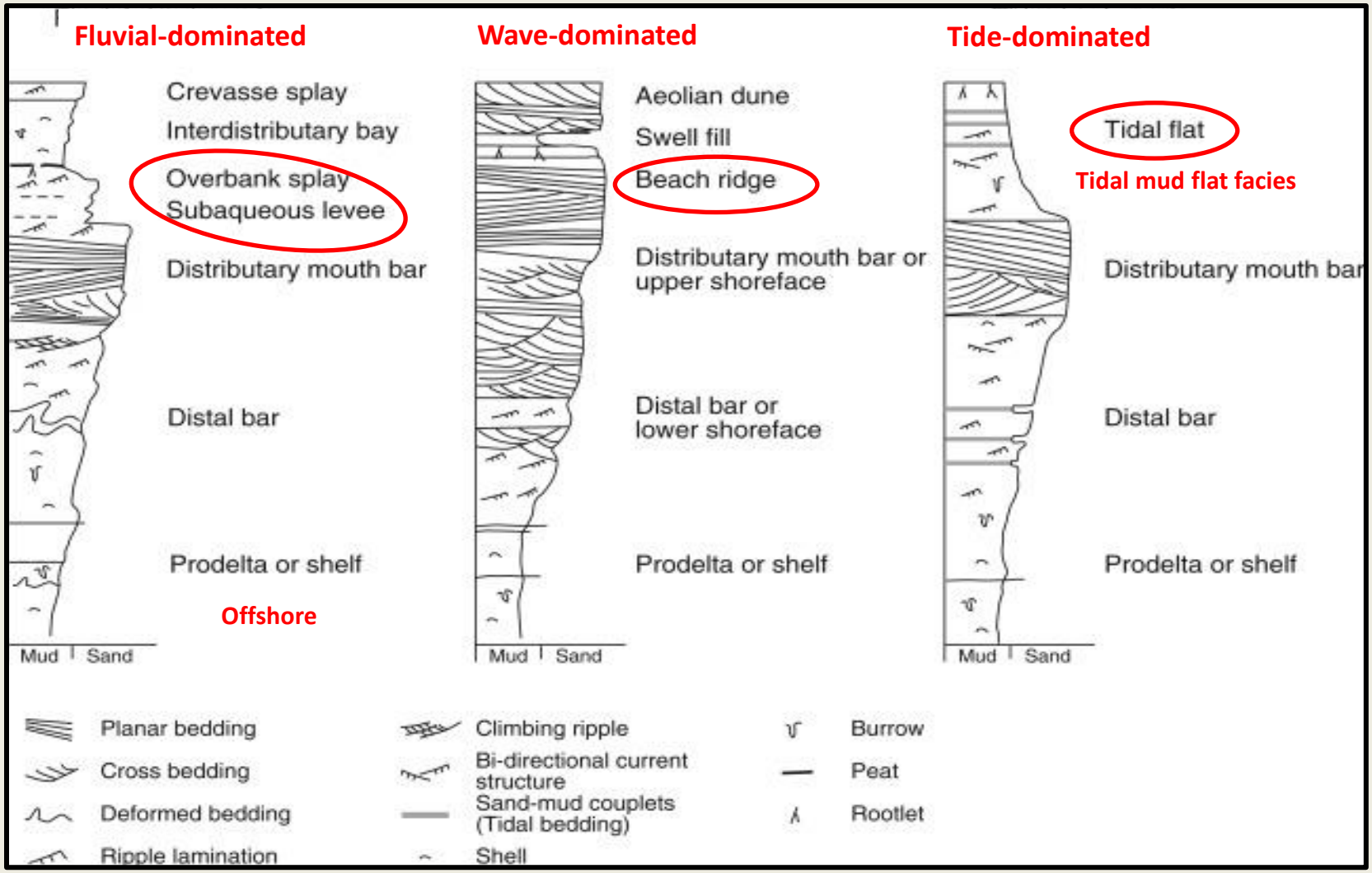


Figure 10: Idealized facies successions of fluvial, wave and tide-dominated facies delta (Modified Coleman and Wight, 1975).

A deltaic lobe:- *is a wetland formation that forms as a river empties water and sediment into other bodies of water*. As the sediment builds up from this delta, the river will break away from its single channel and the mouth will be pushed outwards, forming a deltaic lobe. *When the rate of water discharge and lobe progradation are sufficiently high, a river can form a deltaic lobe*.

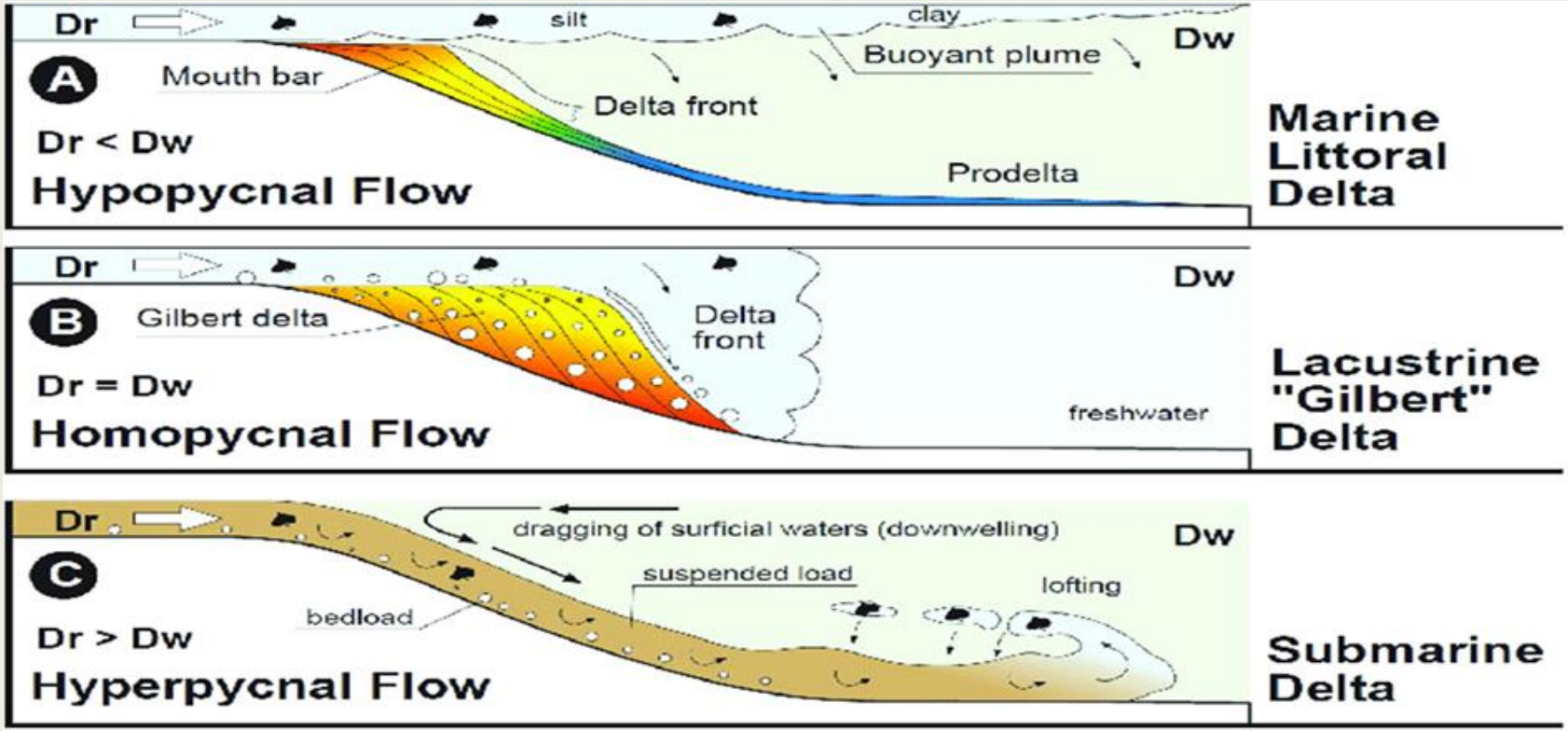


Figure 11: Classification of deltas according to Bates (1953), considering the relationship between the density of the incoming flow (river discharge or Dr) respect to that of the receiving water body (lake or sea, or Dw). A) Hypopycnal flow （Dr<Dw) .B) Homopycnal flow (Dr=Dw). C) Hyperpycnal flow (Dr>Dw).

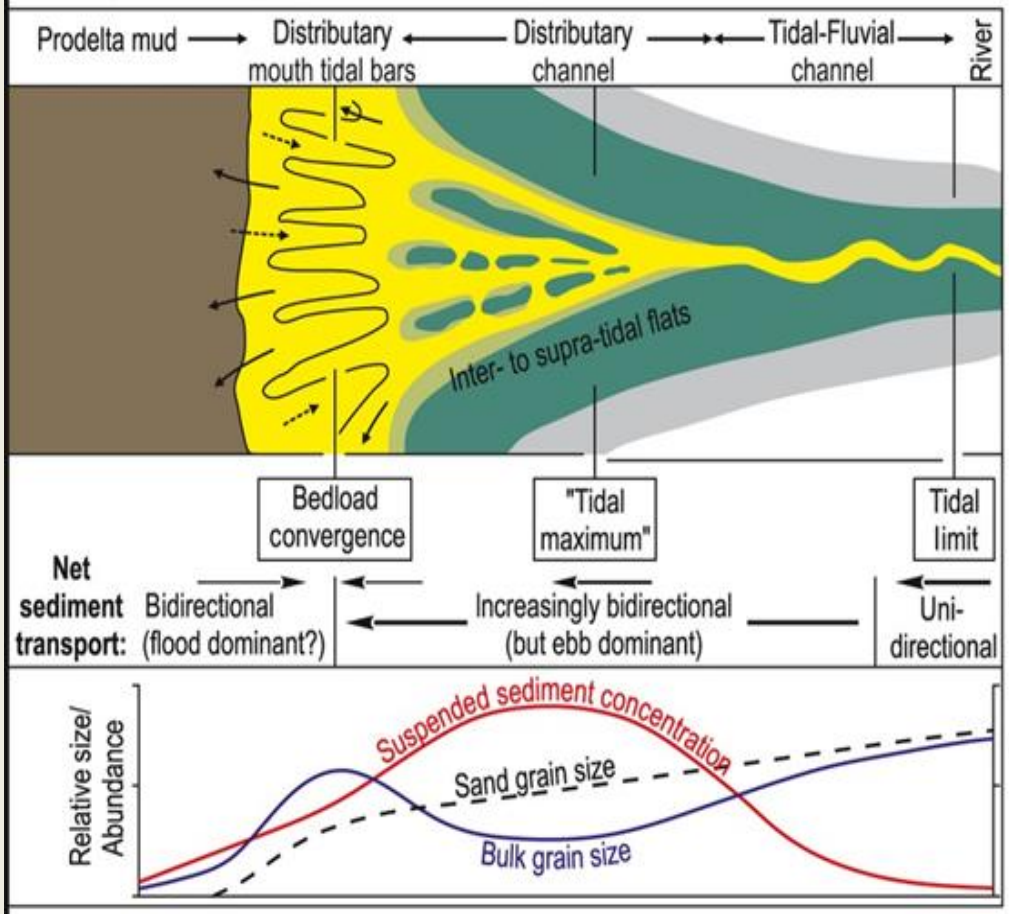
5-8 Wave-dominated delta

Strong wave action at the delta front reworks mouth-bar sands to form coastal barrier and beach ridges (Figure 10). A sand body is produced parallel to the delta-front, although it will be cut through distributary-channel deposits (Figure 10*). A coarsening-up wards unit is still produced through wave-dominated delta progradation*. A package of planar cross-bedding should show low angle. *Paleocurrents basically be bimodal, onshore and offshore-directed, and even polymodal.*

5-9 Tide-dominated delta

Theses occur when the tidal range is high and the reversing ebb-and flood tidal currents are the principal mechanism of sediment dispersal at the delta front. *This succession produced by progradation of tide-dominated delta should be thick coarsening-up wards package*. Muds passing up into sands showing tidal structures, cut through by major channel filled with sand, again with tidal bedding and include tidal mud-flat facies (Figure 10). *Finally deposits of tide-dominated delta is distinguished from the other deltas by the presence of sedimentary structures and facies which indicate of tidal process*.

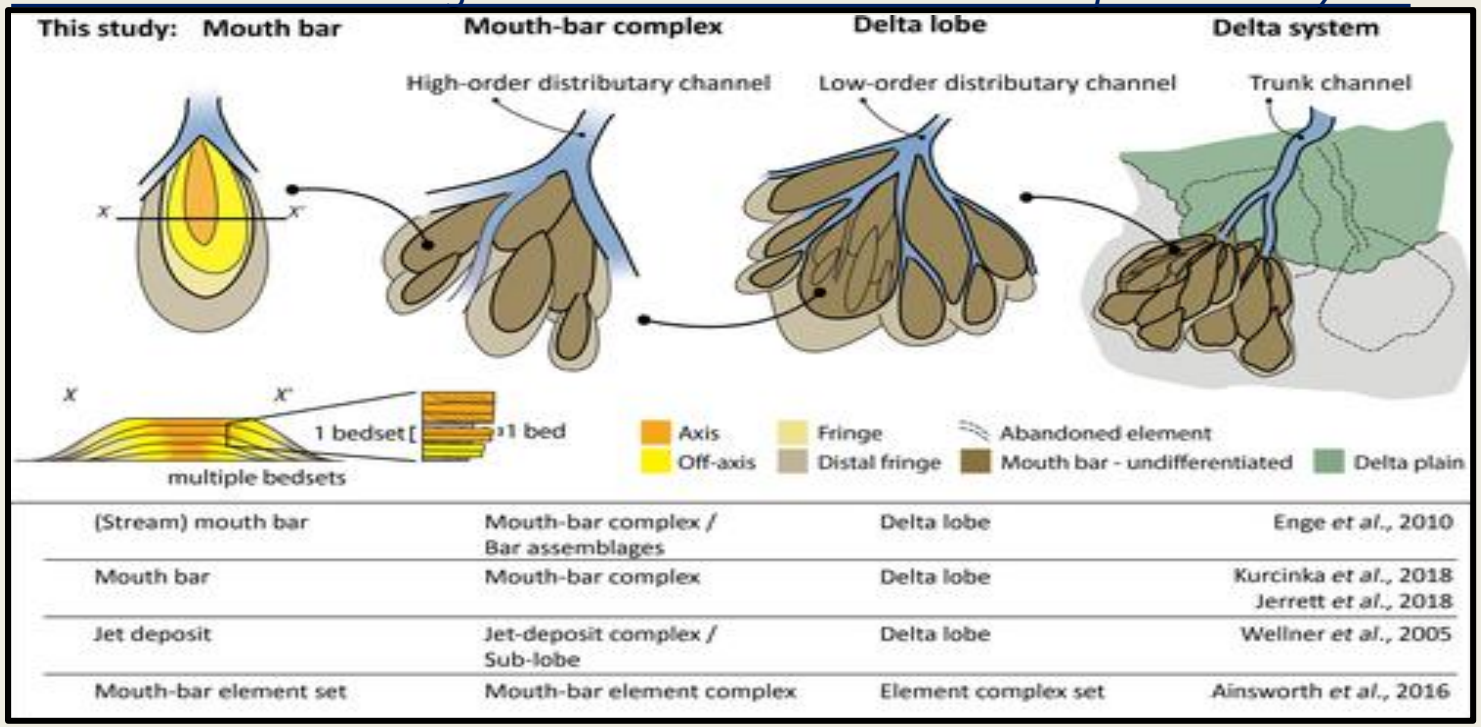
A Tide-dominated delta:



- Regressive depositional system
- Either gradational coarsening upward succession from prodelta into tidal bar deposits, or sharp, erosive base caused by tidal scour
- Tide-dominated deposition in tidal bars at delta front and in distributary channels
- Bedload derived from fluvial source; net seaward fining
- Maximum of suspended sediment concentration in zone of distributary channels, but also high concentration in distributary mouth tidal bars
- Zone of maximum tidal current energy lies within straight distributary channels and landward of bedload convergence
- Delta plain distributary channels: elongate, erosively-based lateral and mid-channel bars showing mainly lateral-accretion (with IHS and fining upward facies profiles); abundant and thick fluid mud
- Distributary mouth tidal bars: mutually evasive channels separate straight, elongate tidal bars; locally fluid mud in channel bases

5-10 River-mouth bar (Delta)

Is a fundamental element to constitute a delta system, ***and its internal facies architectures*** *are vital to reconstruct delta evolution history and study high-resolution sequence stratigraphy* (Miall, 2000; Su and Fan , 2018). Mouth-bar depositional cycles consist of *deposition, extension*, *avulsion* and *abandonment* (Olariu and Bhattacharya, 2006). Mouth bars consist of one or multiple bedsets, in turn composed by a succession of beds that reflect flood and interflood variations in flow conditions and sediment input (Figure 12) (Dalrymple et al., 2015; Gugliotta et al., 2016). *Delta lobes consist of mouth-bar complexes related to the same primary distributary feeder channel (Ainsworth et al., 2016). High sediment supply and/or low-accommodation settings accelerate these mouth-bar depositional cycles.*



(Stream) mouth bar	Mouth-bar complex / Bar assemblages	Delta lobe	Enge *et al.*, 2010
Mouth bar	Mouth-bar complex	Delta lobe	Kurcinka *et al.*, 2018 Jerrett *et al.*, 2018
Jet deposit	Jet-deposit complex / Sub-lobe	Delta lobe	Wellner *et al.*, 2005
Mouth-bar element set	Mouth-bar element complex	Element complex set	Ainsworth *et al.*, 2016

Figure 12: Coalescence of individual mouth bars forms mouth-bar complexes and delta lobes, which together form the building blocks of a delta system. Mouth-bar complexes are related to the same pulse of progradation and their shallow distributary channel network are genetically linked. Delta lobes consist of mouth-bar complexes related to the same primary distributary feeder channel.

5-11 Economic aspect of delta deposits

Deltaic deposits are commonly preserved in the geological record as thick, expanded sections of predominantly clastic sedimentary facies. As already mentioned, these deposits are of great economical importance. They contain vast reserves of hydrocarbons, both solid, in the form of coal, and fluid, as gas and oil (Elliott, 2005). *Because deltaic sediments are commonly rapidly deposited, with little reworking, organic matter is preserved in them. When buried and heated, this organic matter may generate oil and gas. In humid climates, the waterlogged surfaces of deltas are colonized by lush vegetation that is preserved in anaerobic marshes and swamps*. These environments are sites of formations of peat that can accumulate to significant thicknesses due to the high subsidence rates that prevail in deltas. When beds of peat are buried and heated, they metamorphose into lignite (brown coal), then bituminous coal, and finally anthracite.

Most of the coal deposits of the world occur in deltaic deposits of Carboniferous age, and most of the lignite (brown coal) deposits of the world occur in Tertiary deltas.

-Furthermore, deltas generate their own petroleum traps. *The deltaic process is a way of depositing lobes of sand (potential reservoirs) into envelopes of organic-rich marine muds (potential source beds)*. Deltaic environments deposit many potential stratigraphic traps, including mouth bars, barrier bars, and channels. *Rapid deposition often leads to overpressuring.* This may generate diapiric traps and roll-over anticlines. *Deltas need a basin, or at least some subsidence, before they may form* (Figure 13).

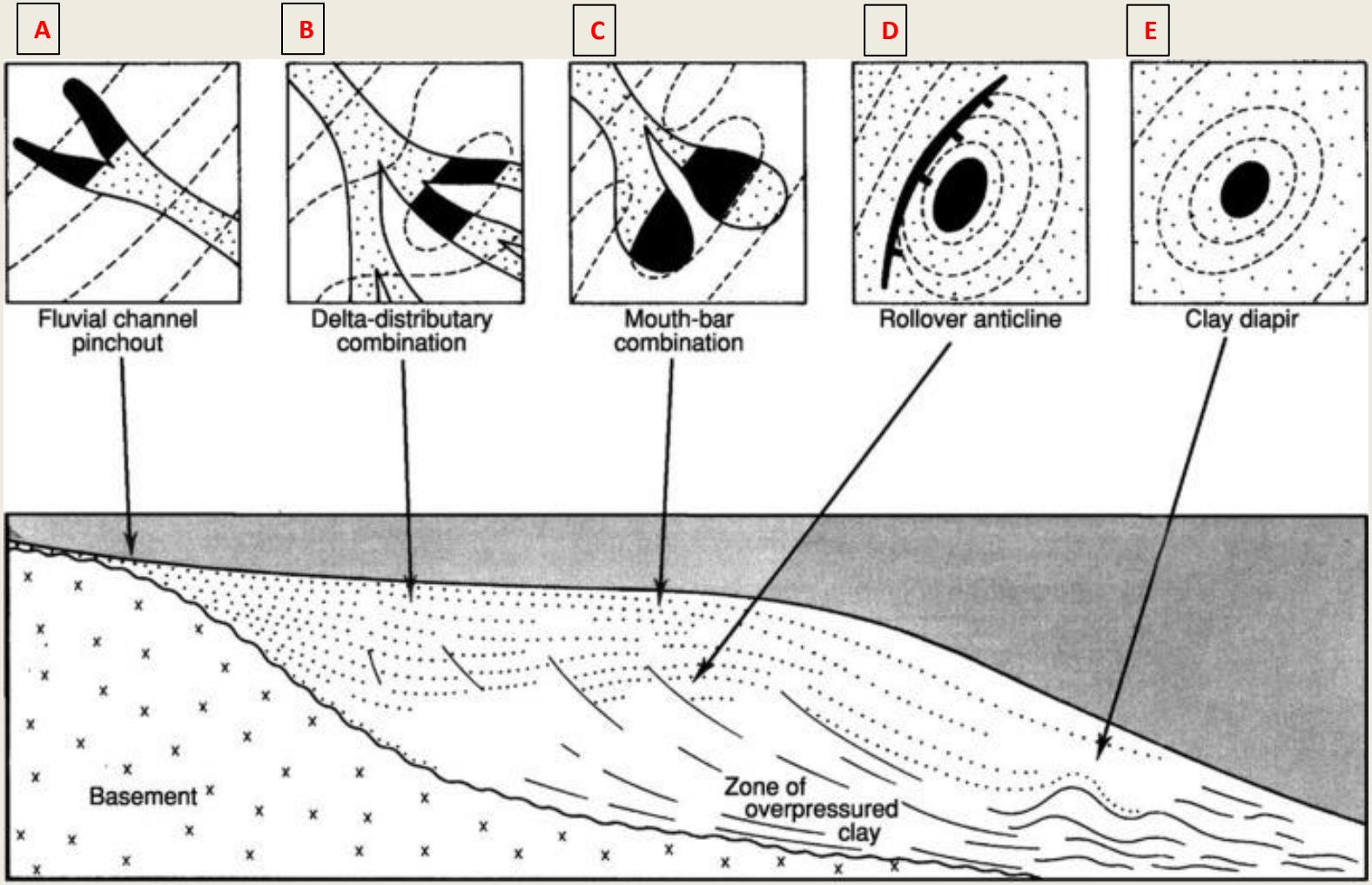


Figure 13: Cross-sections and illustrations of the modes of petroleum entrapment in deltas. Note that the alluvial pinch-out (A) is a simple stratigraphic trap. Types (B) and (C) are combined stratigraphic and structural traps. Types (D) and (E) are both contingent on the presence of Overpressured muds in the distal part of the delta. Examples of each type of trap are cited in the text.

Text Book Review

1-Principles of Sedimentology& Stratigraphy by Boggs, 2006 Page 289-301
2-Sedimentology 7 Stratigraphy by Nichols, 2009 Page 179-205
3-Sand and Sandstones by Pettijohn et al., 1987. Page 321-337

Homework*: Write briefly Impact of deltaic facies analysis with reservoir rocks.

Facies Pattern:-

1-Aggradation Sediment supply = Accommodation space (facies constant).
2-Progradation Sediment supply > Accommodation space (Shallowing up-ward). Delta successions.
3-Retrogardation Sediment supply < Accommodation space (Deepening up-ward).

Progradation Facies:- it means move shoreline to seaward as a result in sedimentation occurring . It is really shallowing upwards (Delta successions).

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