Lecture II

Sedimentary Environments and Facies

Definition of sedimentary environment and Facies

- ***A sedimentary facies*** **is a mass of sedimentary rock can be defined and distinguished from others by its geometry, lithology, sedimentary structures, paleocurrent pattern and fossils**

- ***A sedimentary environment*** **is a part of the earth's surface which is physically, chemically, and biologically distinct from adjacent terrains.**
- **For examples: deserts, river, deltas.**
- A sedimentary environment may be a site of erosion, non-deposition, or deposition

Facies definitions

- **A facies is a body of rock with specified characteristics. It is defined on the basis of colour, bedding, composition, texture, fossils and sedimentary structures.**
- **Lithofacies refer to described rock unit.**
- **A facies should idealy be a distinctive rock that forms under certain conditions of sedimentation, reflecting a particular process or environment. Facies may be subdivided into subfacies or grouped into facies associations or assemblages.**

The relatioship between sedimentay environments and facies

Table 1.1. The relationship between sedimentary environments and sedimentary facies.

CAUSE →				EFFECT
Process				
Physical	SEDIMENTARY ENVIRONMENT	Erosional		Geometry
Chemical		Non-depositional		Lithology
Biological		Depositional →	SEDIMENTARY FACIES	Sedimentary structures
				Palaeocurrents
				Fossils

Factors controlling the nature and distribution of facies

Sedimentary processes ➡

It means processes intrinsic to sedimentation, be responsible for facies distribution and changes. Progradation of deltasGradient of rivers Slope of submarine. Differentaial compaction of underlying sediments(salt domes, growth of faults

Sediment supply ➡

control on the thickness of facies In transgressive, when subsidence and rise of sea level took place, deepening facies occur and chemically sediments formed. During regressive, the increase sediment supply took place, progradation took place , continental facies occurs

Climates ➡

Humid climate, increase rain fall, terrigenous facies result. Arid to semi arid climate sporadic rain fall and fluctuations, carbonate dominated facies result

Factors controling the nature and distribution of facies

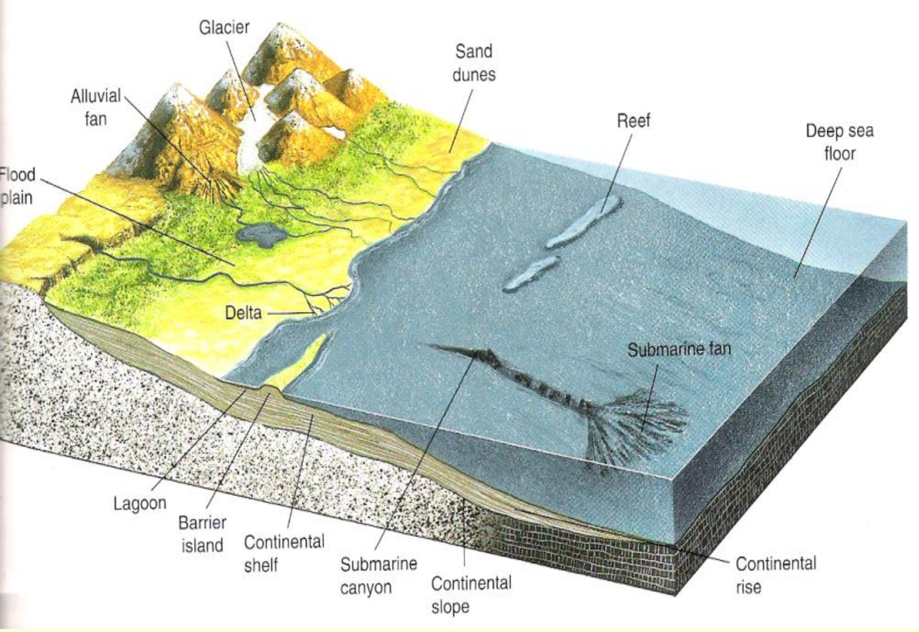
Sea level changes → Sea level changes have resulted from the freezing of water in polar ice caps.Retrgradation of facies during rising sea level. Progradation of facies during falling sea level

Tectonics → Tectonics cause local facies changes, Vertical movements, tilting of fault blocks, onlaping, donlaping

Water chemistry → It means the salinity and composition of sea water and lakes. The saturation with $CaCO_3$, carbonate deposits result The saturation with $CaSO_4$, evaporite facies took place

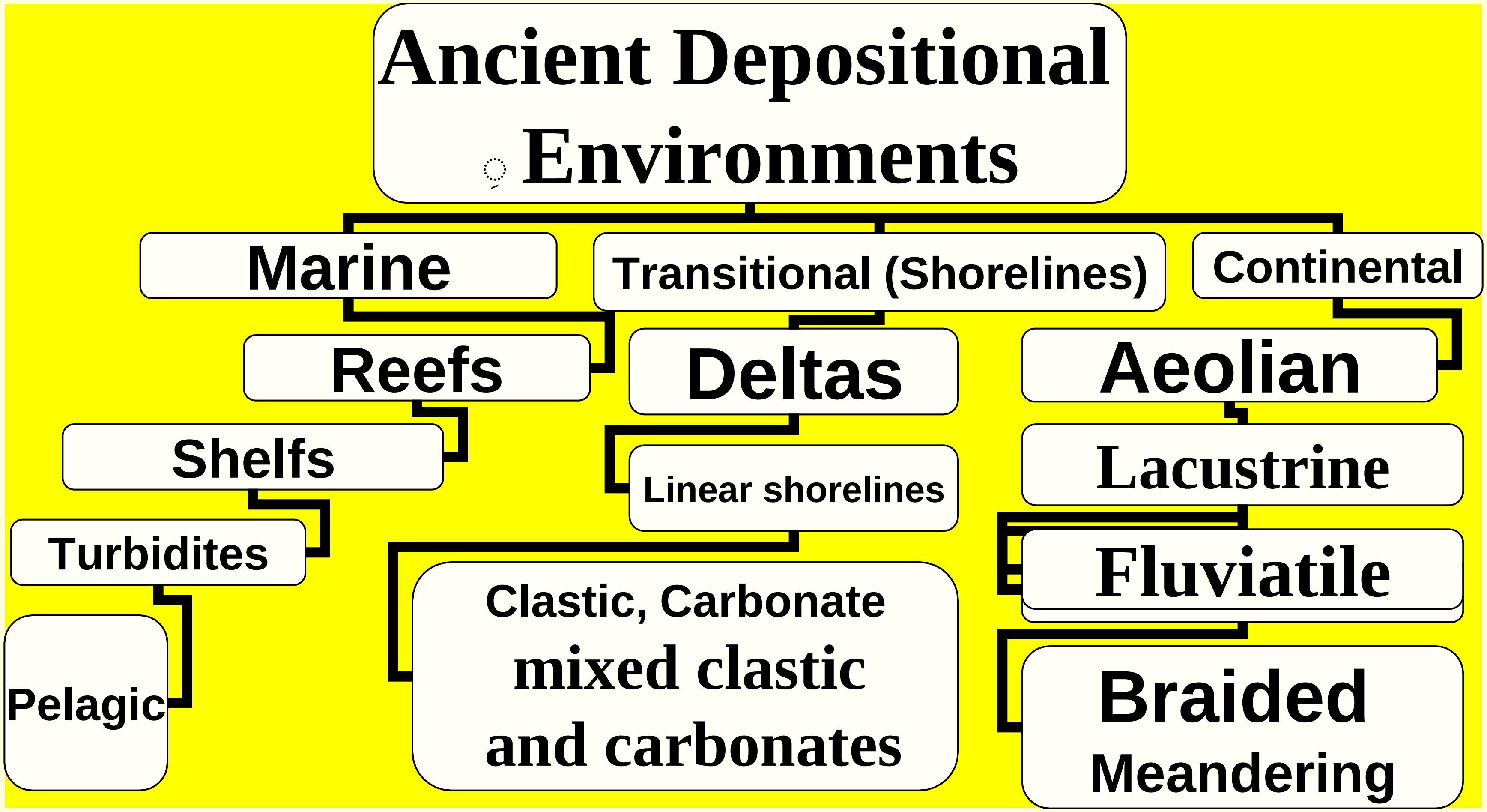
Volcanism → Volcanism provides a local, intrabasinal source of sediment and ions of solution, leaching of hot lavas by sea water, clay minerals formed .Hydrothermal discharges of metal-rich fluids are important in pelagic facies . There many a close connection between composition of the volcanic source and lake precipitation

A classification of depositional environments

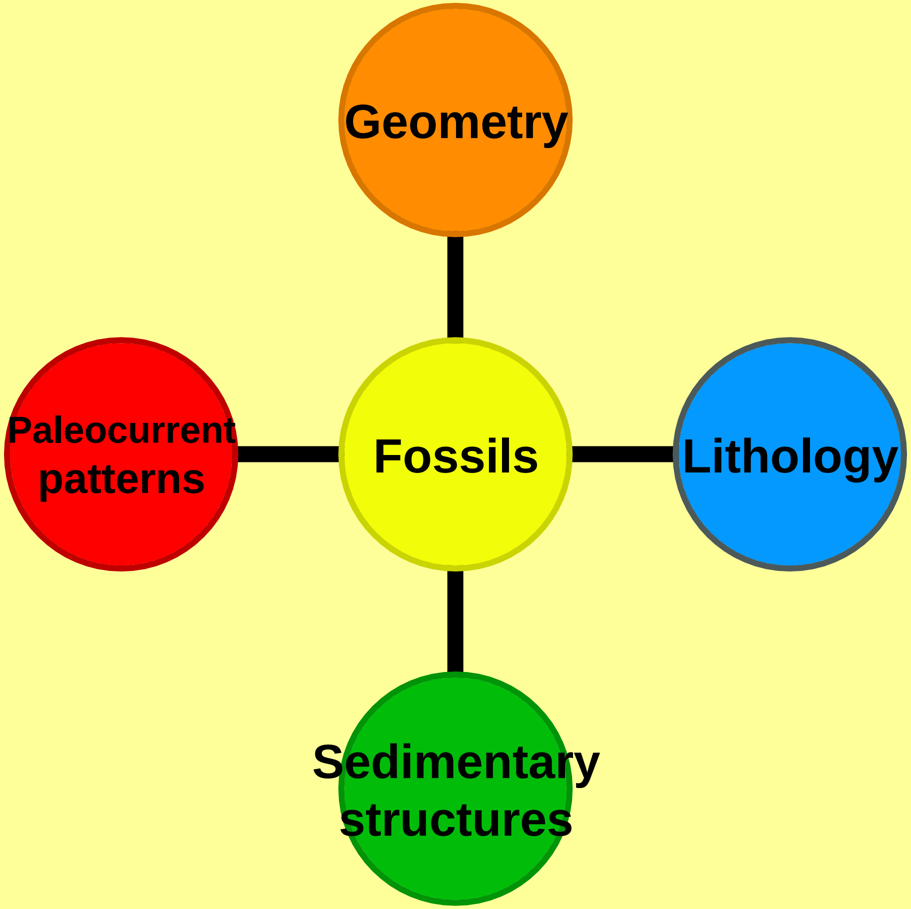


Continental	Fluviatile	Braided Meandering
	Lacustrine	
	Eolian	
Transitional (Shorelines)	Lobate (deltas) Linear	Terrigenous Mixed carbonate: terrigenous Carbonate
Marine	Reef	
	Shelf	
	Submarine channel and fan	
	Pelagic	

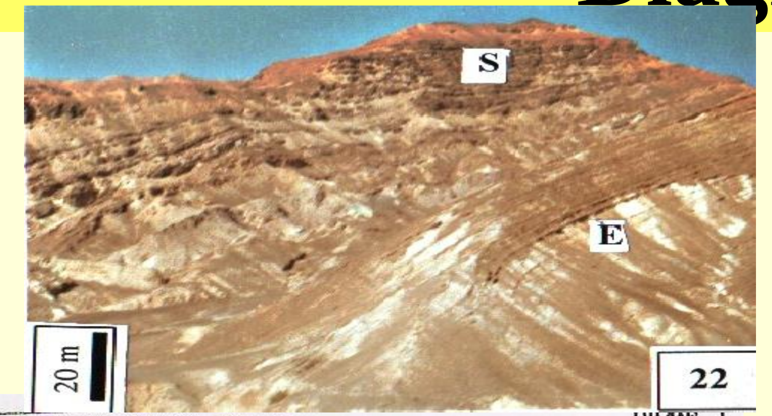
A classification of depositional environments

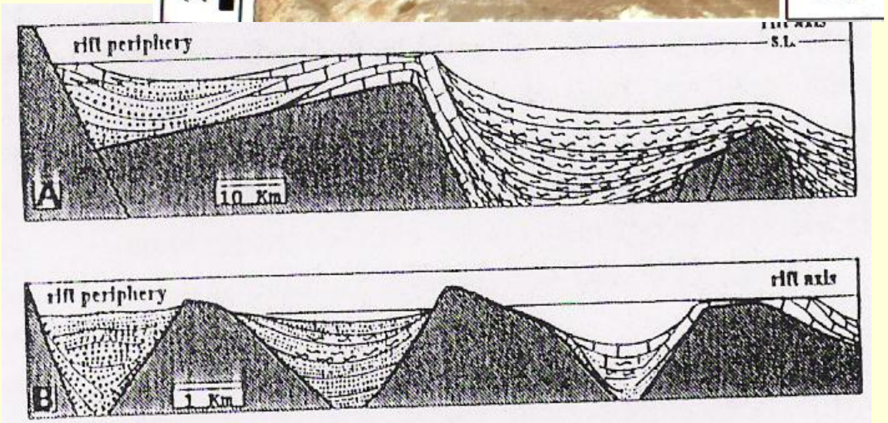


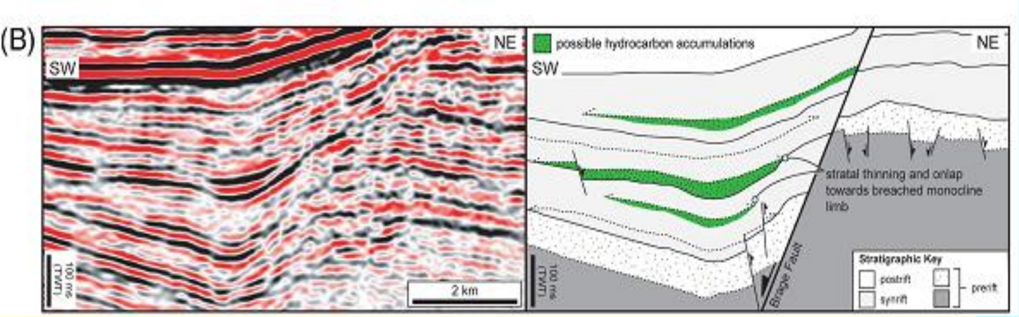
Methods of Environmental Diagnosis



Methods of Environmental Diagnosis



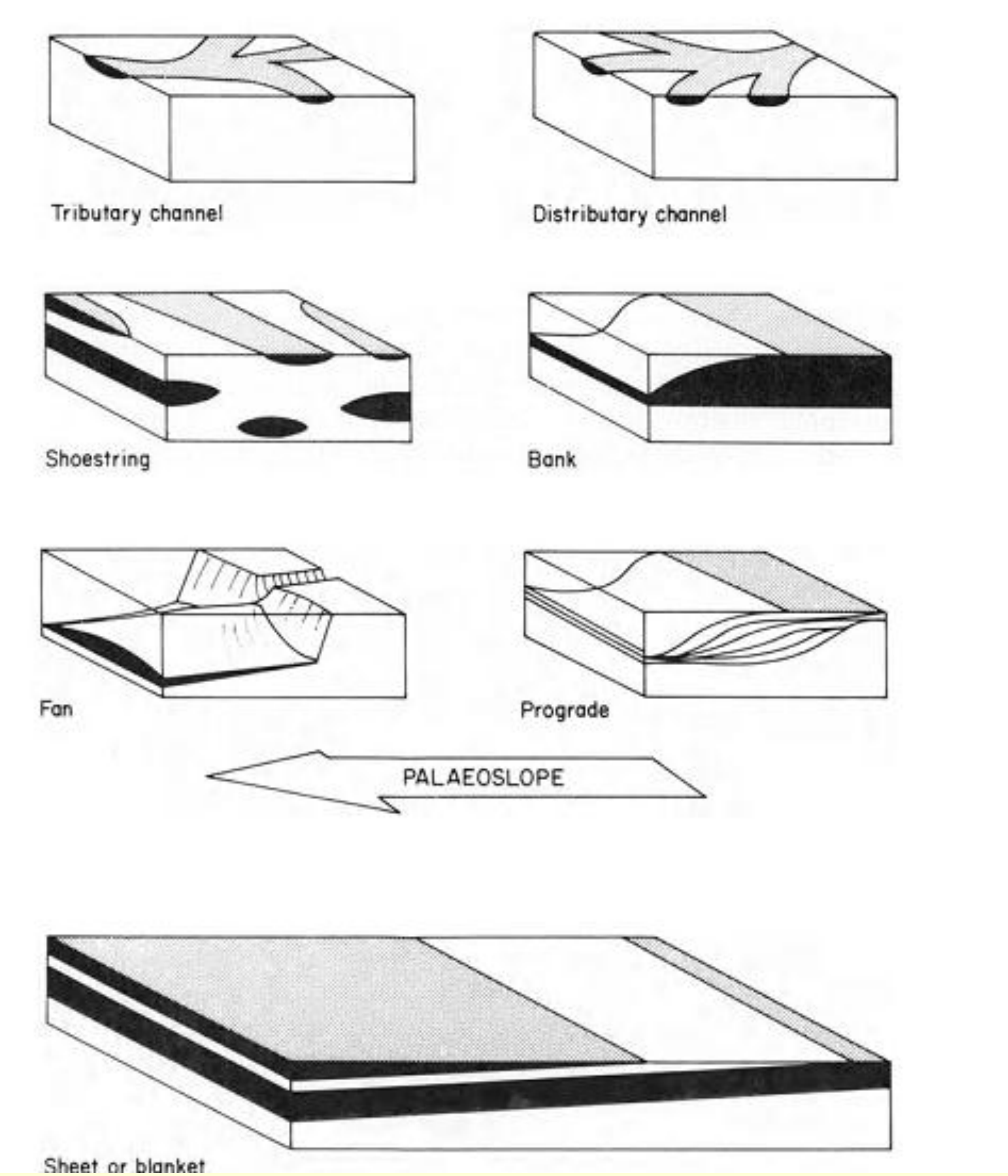




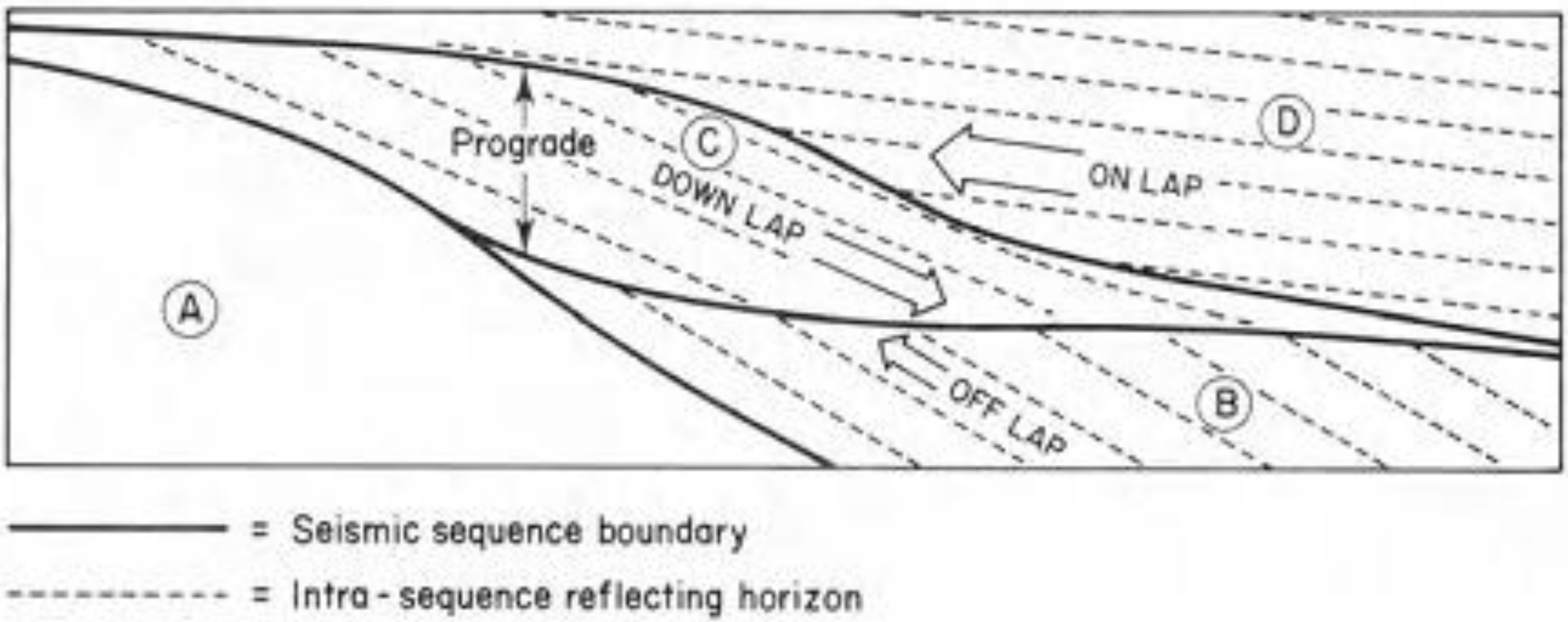
- **1- Geometry:**
- **Geometry may easy to determine where crops out and exposure at the surface. The over-all shape of a sedimentary facies is a function of different factors:-1- Pre-depositional topography, 2- geomorphology of the basin, 3- post depositional history (tectonics and erosion)**

- **It is important to note that the same geometry may be produced in one of several different environments. Channels may be fluvial, deltaic, tidal or submarine. Fans may be alluvial, deltaic or deep marine.**

In the subsurface, seismic surveys make it possible to map the geometry of facies; onlap (retrogradational) or downlap(progradational). Modern reflection seismic can delineate the geometry of submarine fans, outlines reefs, fore sets deltas

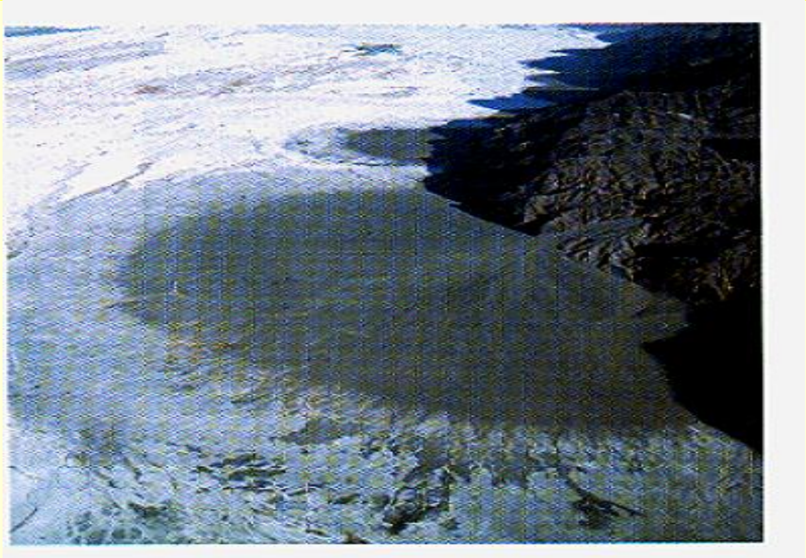


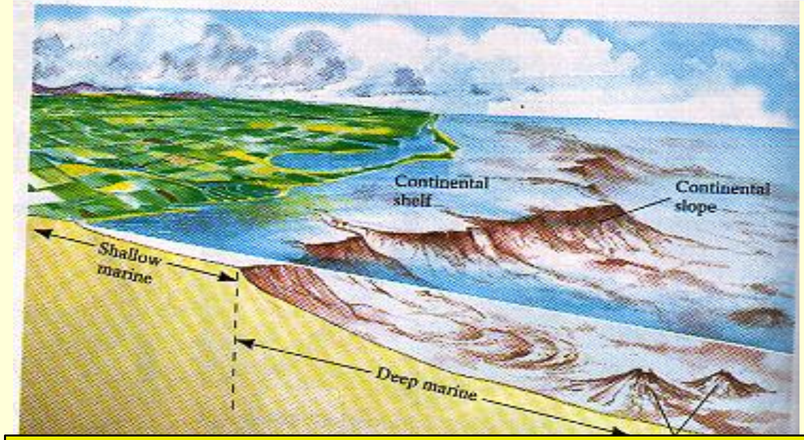
Cartoons of various facies shapes.

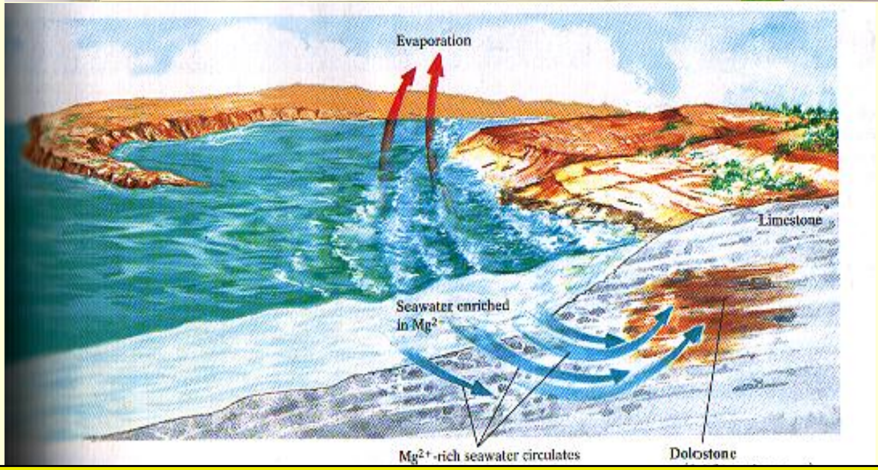


Sketch to show some of the terminology of seismic stratigraphy.

Examples of Syn-depositional geometry

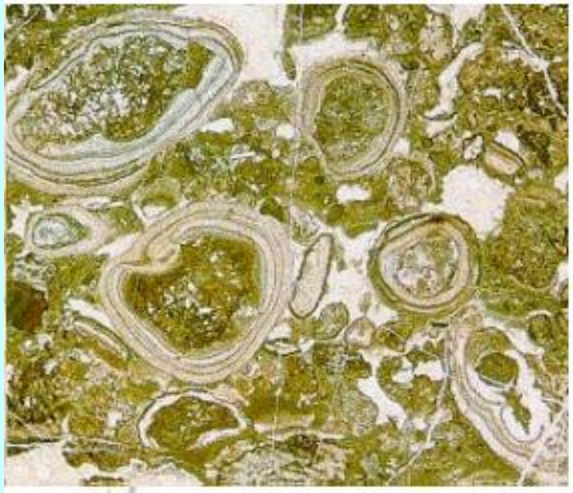


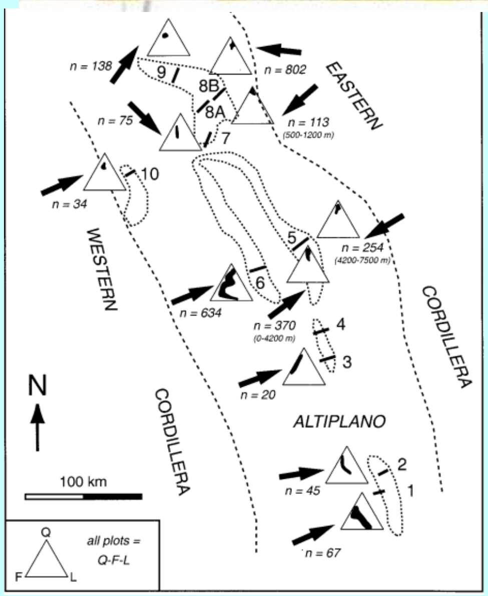




syndepositional shape of the environment when preserved (e.g., alluvial fans and shoestering shapes of offshore bars, radiating channels of deltas)

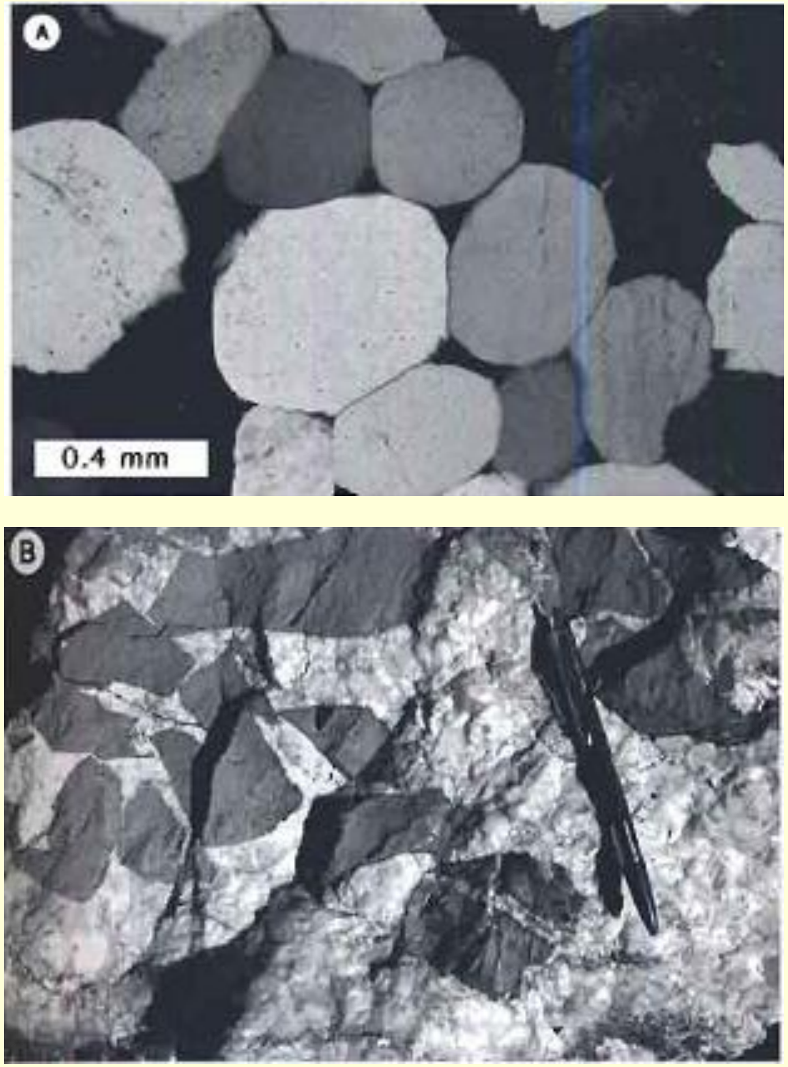
2- Lithology





- **The lithology is an important factor to interpret the environment**
- **Generally the lithology of limestones is more diagnostic importance than that of sandstones**
- **The lithology of sandstones gives less indication of their depositional environment. However clastic rocks give indications to history of transport and the nature of the source rocks, and of the type of rock from which it was derived**
- **Many attempts have been made to use the texture of a sediment to determine its depositional environment.**
- .

2- Lithology



- Shape of sand grains, sorting and texture are more important; more angular sands in glacial environments, in dune environments the sands are often well rounded

- Also, the grain size of a sediment (clastic rocks) is an indicator of energy level of depositional environment. The coarser grain size (boulders, cobbles) represents high energy level of the depositional currents.
- In carbonate rocks the grain size is important because many limestones are composed of skeletal particles

Sedimentary structures

provide evidence of an environment was glacial, aqueous, or sub-aerial

They give some indication of the depth and energy level of the environment and of the velocity, hydraulics, and direction

of the currents which flowed across it

3- Sedimentary structures

Post- depositional Sedimentary structures

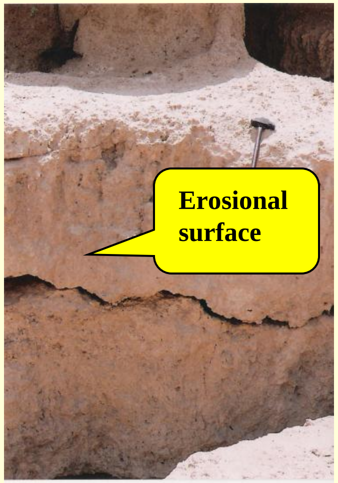
Syn- depositional Sedimentary structures

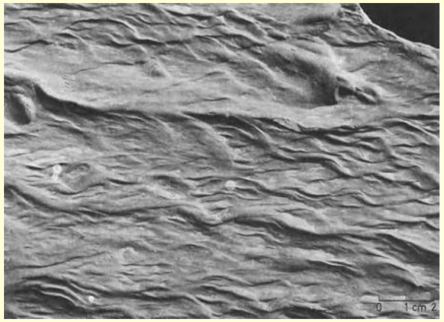
Pre-depositionall Sedimentary structures

A- Pre-depositional

- **Pre-depositional sedimentary structures are those observed on bed interfaces which formed before deposition of the younger bed.**

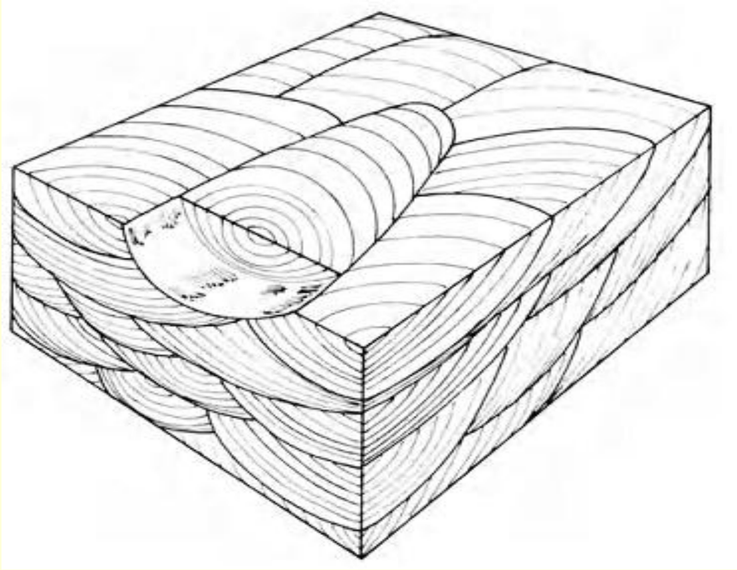
- **They are thus erosional features, Pre-depositional structures include channels, scour marks, flutes, grooves, tool markings, and a host of other erosional phenomena**



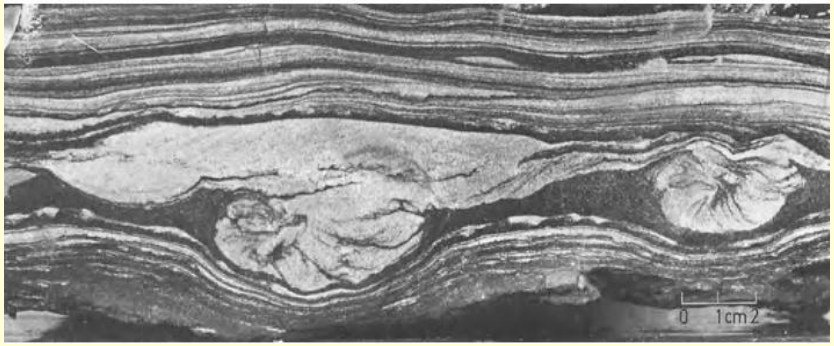


B- Syn-depositional sedimentary structures formed during deposition

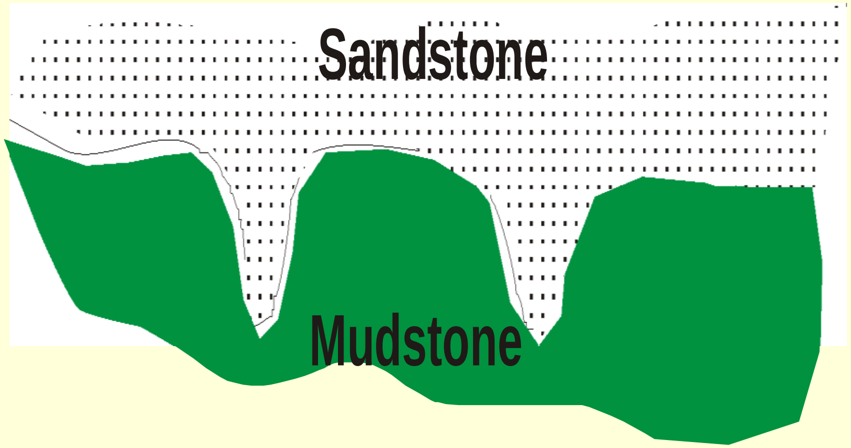
Include, Cross bedding, flat bedding, lamination, ripple marking, large scale aeolian cross bedding, micro-cross-laminations

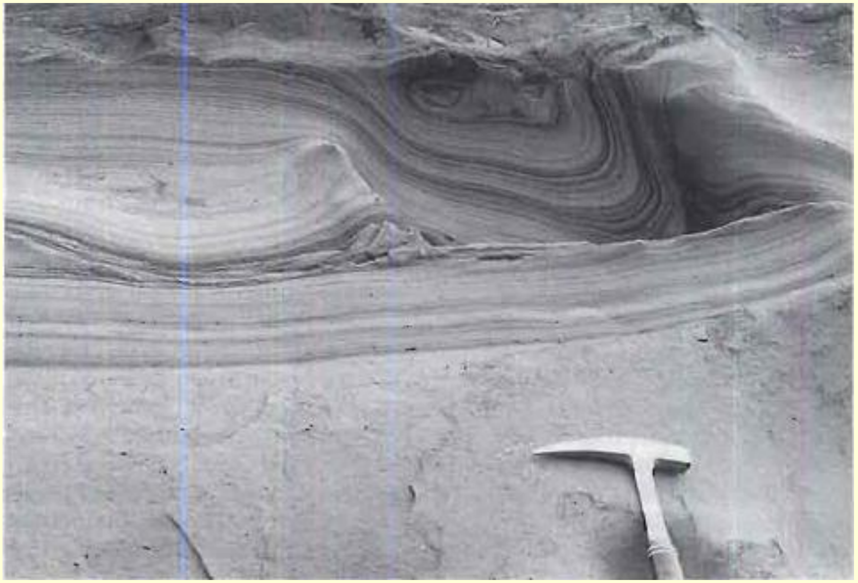


C- Post-depositional sedimentary structures develop in sediments after their deposition



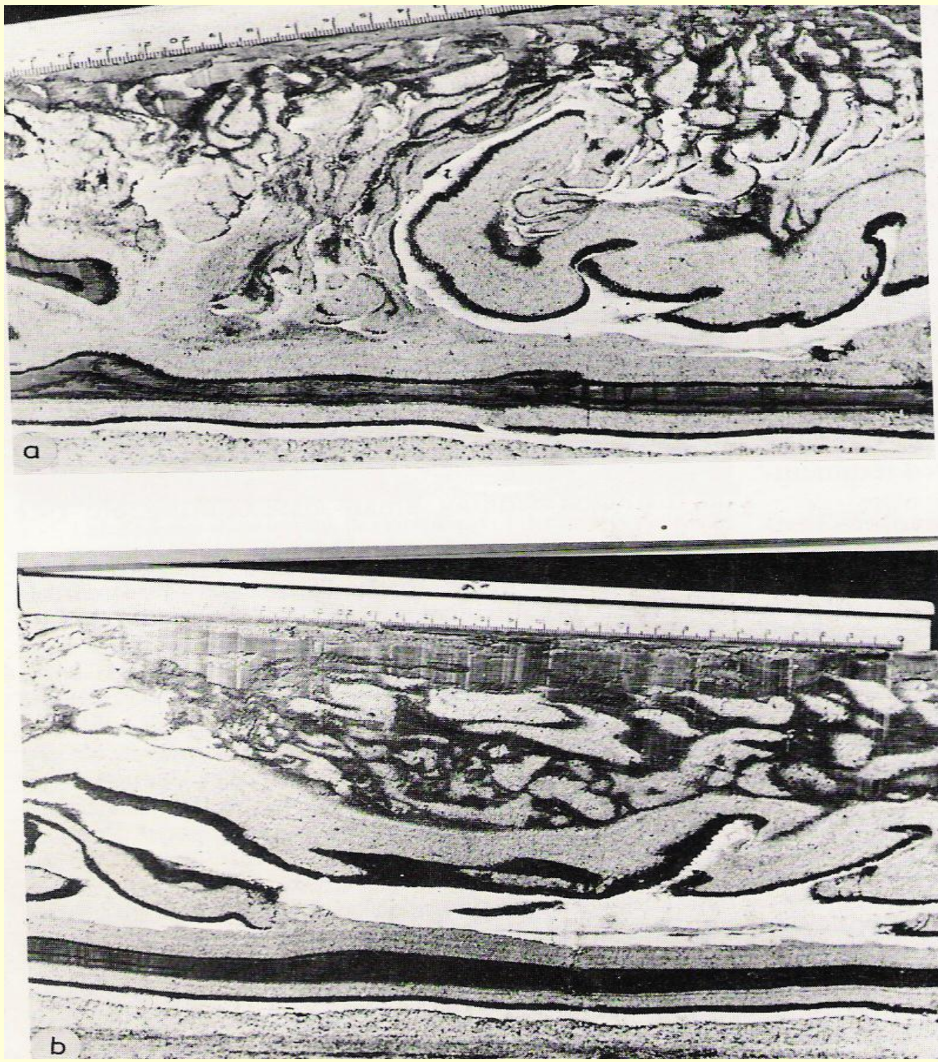
Vertical Reorientation of bedding (load casts,convolute laminations

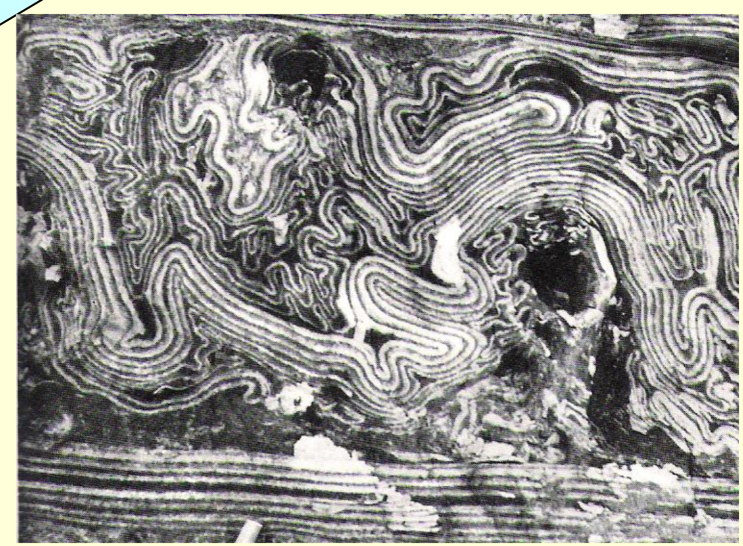




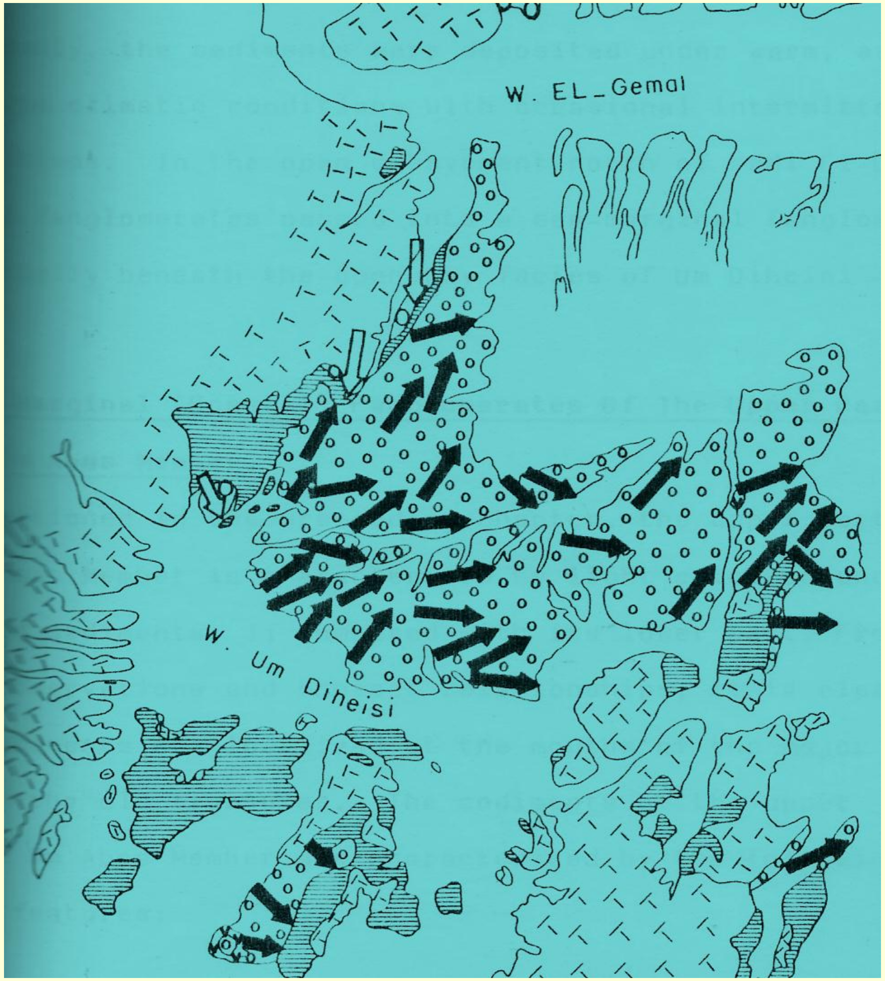
Post-depositional sedimentary structures develop in sediments after their deposition

Lateral
Rearrangement
Of the fabric
(slumping, sliding, distorted bedding)





4- Paleocurrent patterns



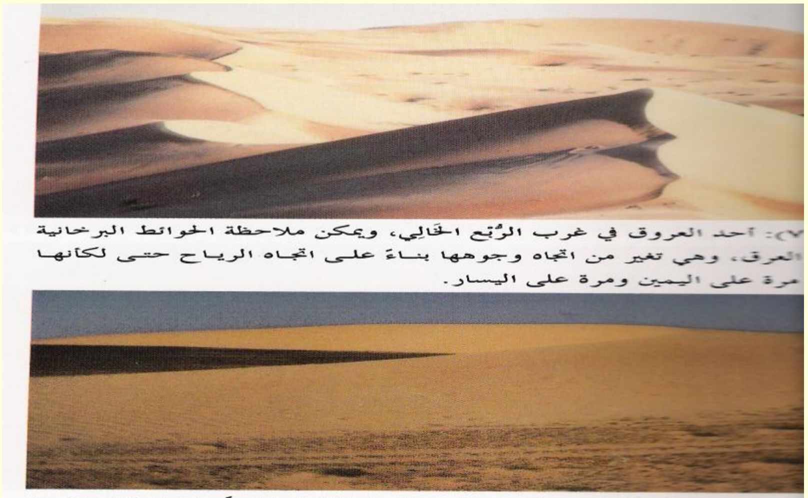
- **Paleocurrent patterns are very important indicators of depositional environment.**
- **The paleocurrent analysis of a facies involves the following steps:**
- **1- Measurement of the orientation of the sedimentary structure in the field (e.g. dip directions of cross bedding, channel axes)**
- **2- Deduction of paleocurrent direction at each sample point.**
- **3- Preparation of regional paleocurrent map.**
- **4- Integration of paleocurrent map with other lines of facies analysis to determine environment and paleogeography. In some environments paleocurrents may indicate paleoslope (e.g. in rivers)**

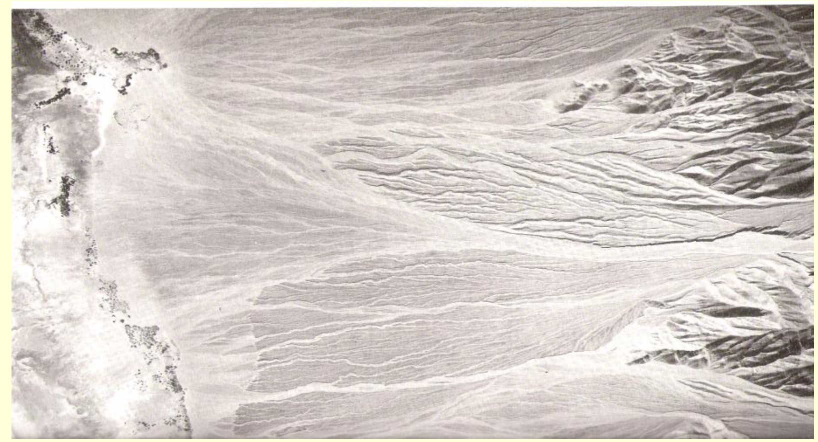

W. EL_Gemal
W. Um Diheisi

Environment		Local current vector	Regional pattern
Alluvial	Braided	Unimodal, low variability	Often fan-shaped
	Meandering	Unimodal, high variability	Slope-controlled, often centripetal basin fill
Eolian		Uni-, bi- or polymodal	May swing round over hundreds of miles around high pressure systems
Deltaic		Unimodal	Regionally radiating
Shorelines and Shelves		Bimodal (due to tidal currents), sometimes unipolar or polymodal	Generally consistently oriented onshore offshore, or longshore
Marine turbidite		Unimodal (some exceptions noted, see p. 253)	Fan-shaped or, on a larger scale, trending into or along trough axes

A classification of some palaeocurrent patterns. Based on data in Selley (1968).

Photos showing different types of paleocurrent patterns





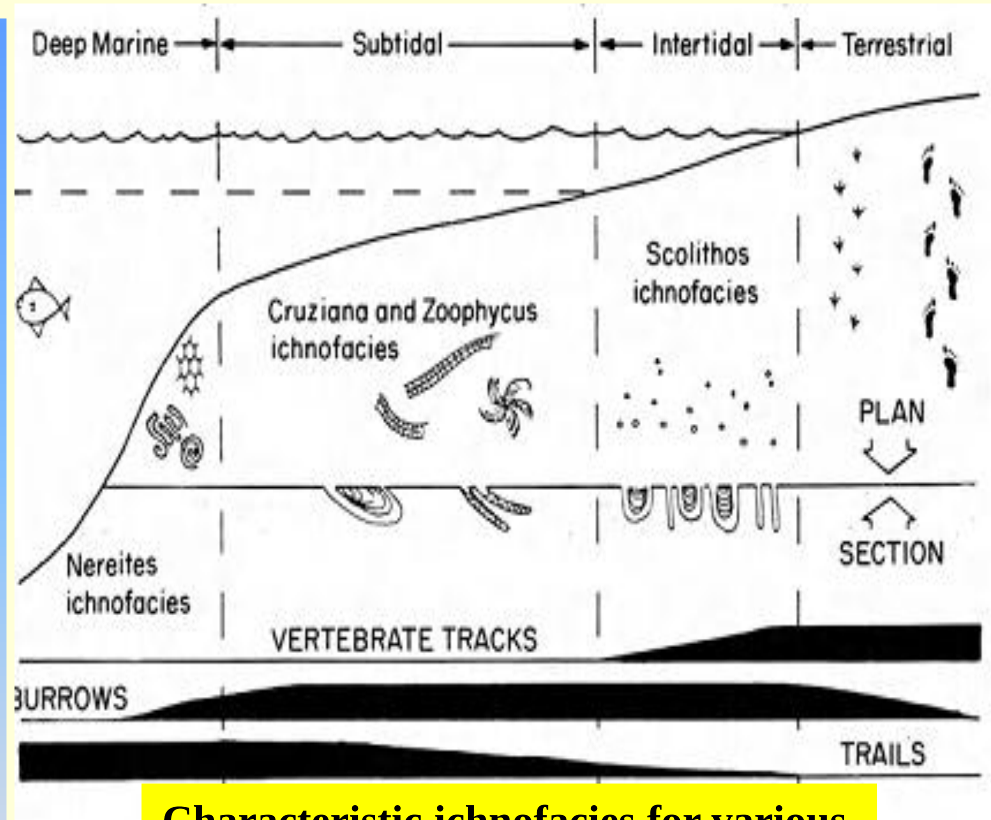
5- Fossils

- These have one of the most important methods of identifying the depositional environment of a sediment.T hey give indications on paleoecology
- Many fossils are preserved in a particular environmnt
- Two of the most important types of fossils used in envoronmental analysis: micro-fossils and trace fossils.
- In the case of micro fossils the small volume of rock contain sufficent specimens to be used in statistical studies.
- The faunal hiatuses are deduced for traceable,
- basin-wide sequence boundaries between depositional sequences . The abrupt changes in lithological character and P/B ratios across a sharply defined surface.
- The maximum flooding surfaces (MFS) are typically interpreted at the
- position marking the maximum P/B value.

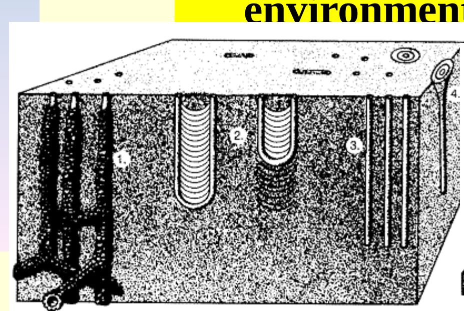
Trace fossils (ichnofossils)

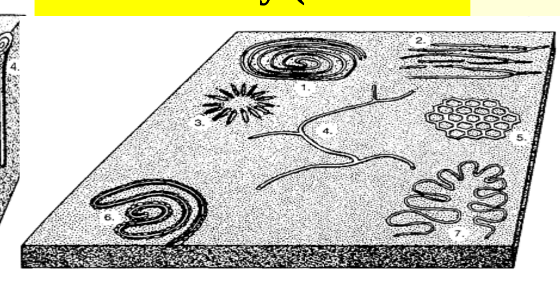
- Trace fossils are useful in environmental interpretation for two reasons, ***First***,
- they occur ***in situ,*** and cannot therefore be reworked like other fossils.
- ***Second***, it has been noted that certain types of trace characterize particular environments. Using this fact workers have defined a series of 'ichnofacies'. Each ichnofacies consists of a suite of trace fossils which occur in characteristic sedimentary facies whose environment may be determined

- One of the most useful groups of fossils for environmental diagnosis is burrows, tracks, and trails, collectively called trace fossils.



Characteristic ichnofacies for various environments. from Selley (1976

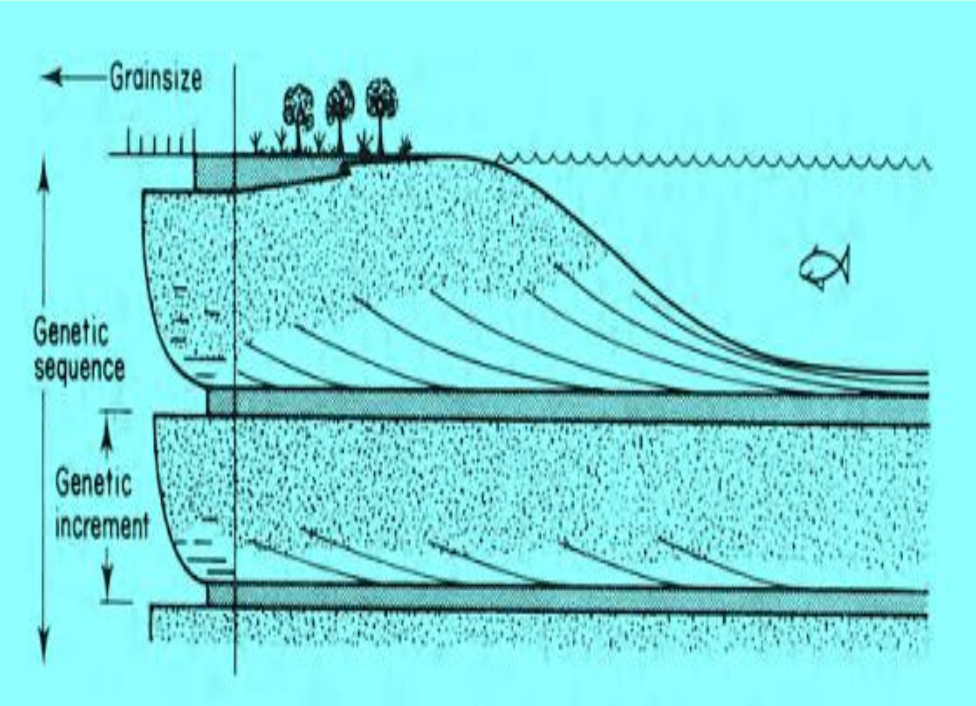




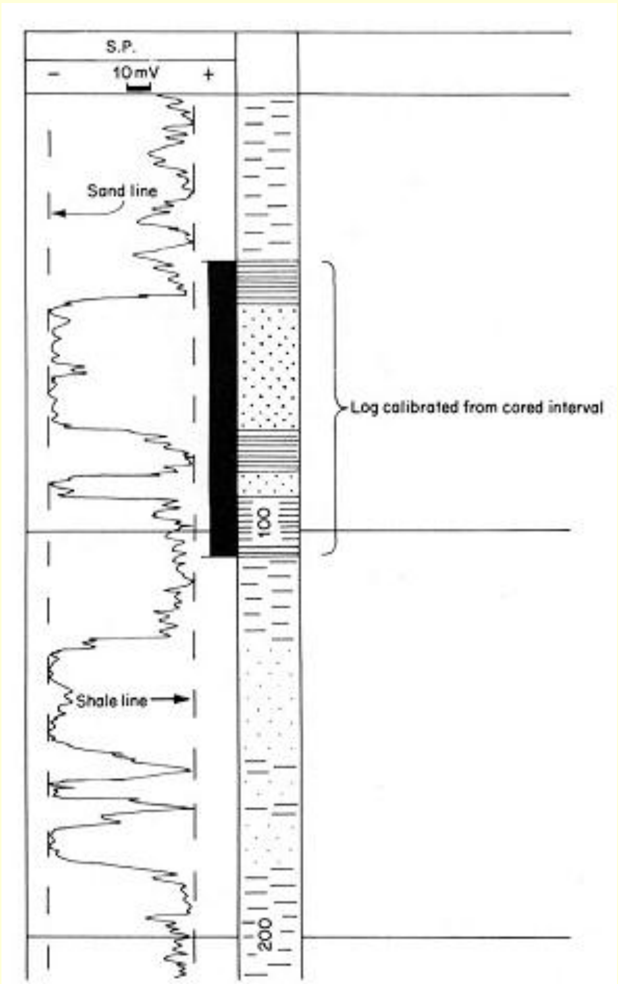
Cyclicity in depositional sequences

- Cycle-generating processes have been classified into two groups defined by
- Beerbower (1964, p. 32) as follows:

- (i) Autocyclic mechanisms: 'are generated in the depositional prism and include such items as channel migration, channel diversion, and bar
- migration. '
- (ii) AI/ocyclic mechanisms: 'result from changes external to the sedi-mentary unit such as uplift, subsidence, climatic variation, or eustatic change

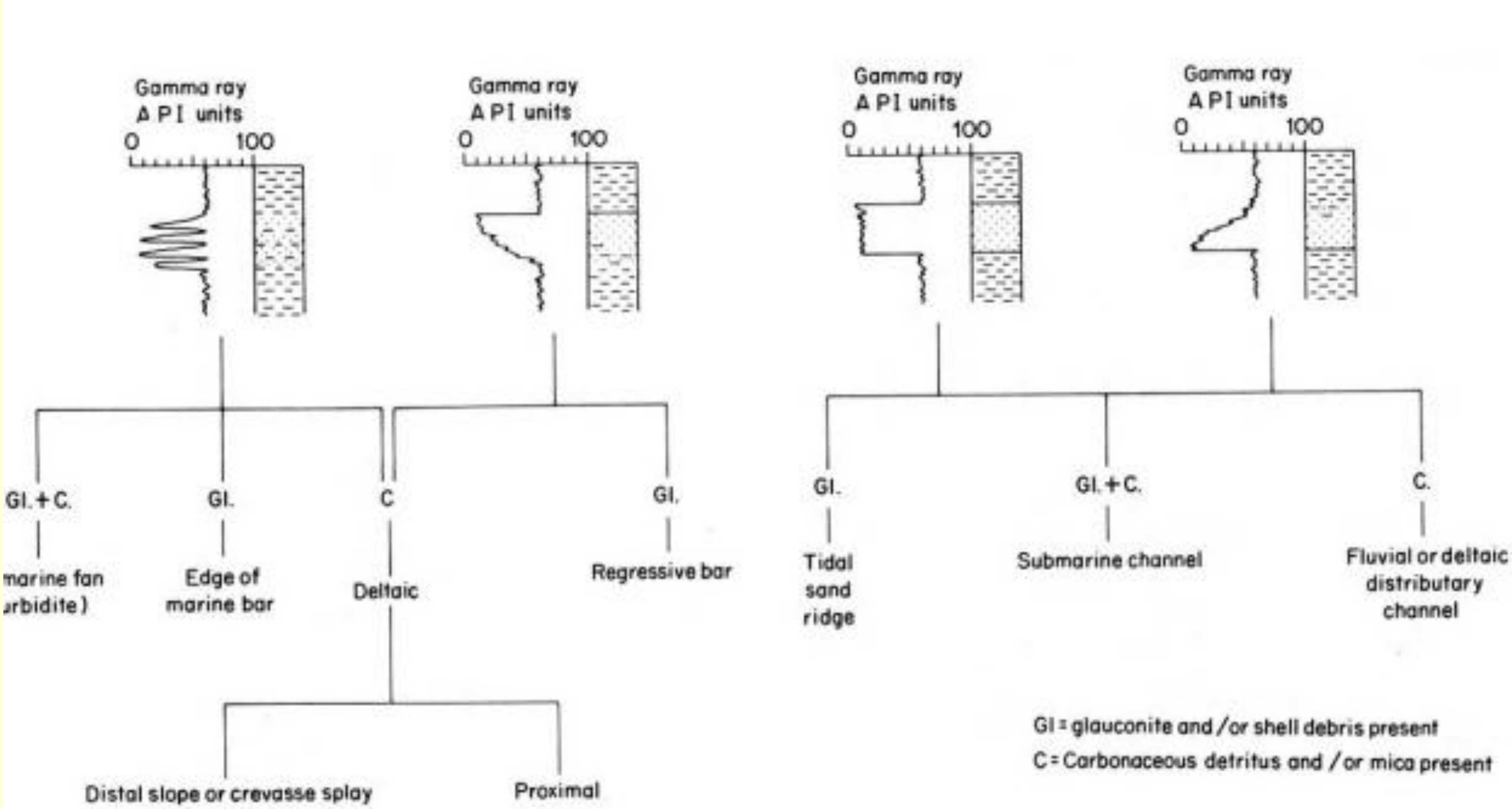


SUB-SURFACE ENVIRONMENTAL INTERPRETATION



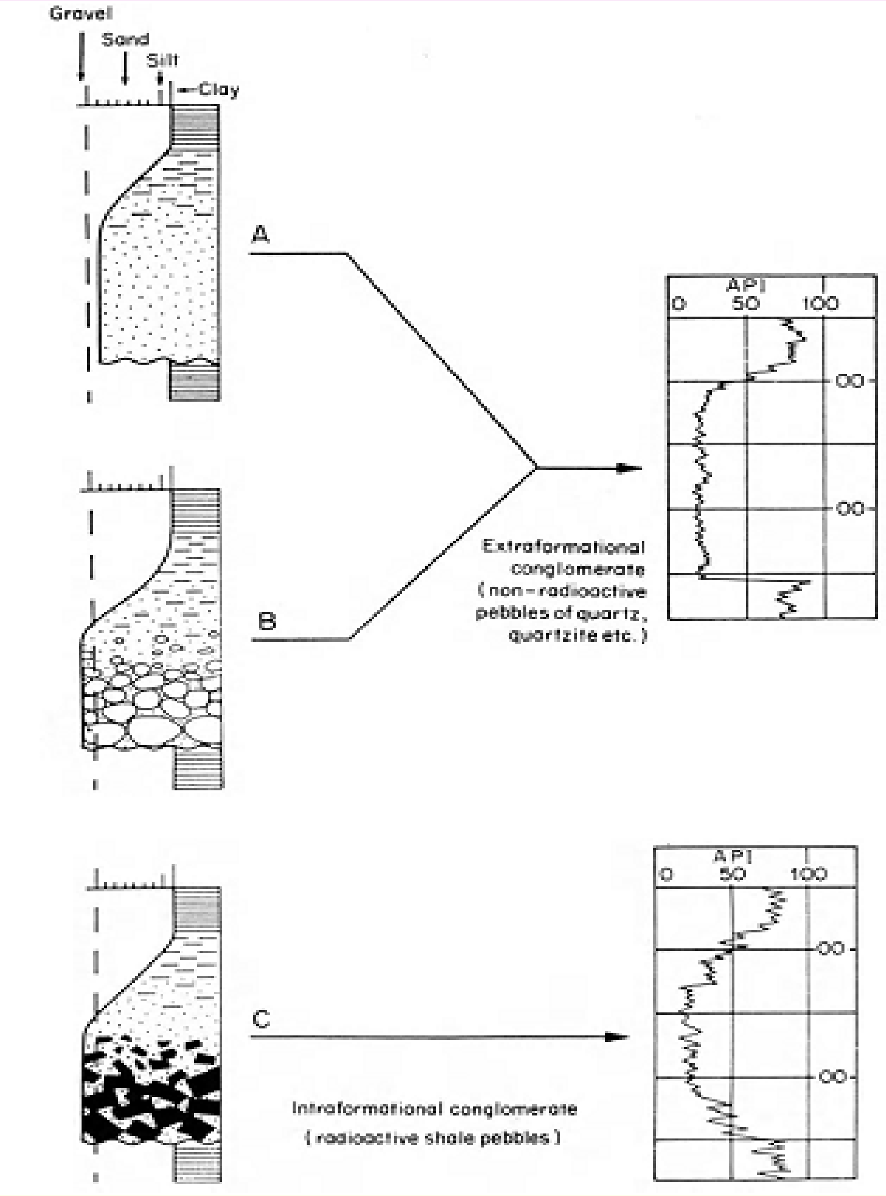
Well log of spontaneous potential (S.P.) curve against depth, showing how sand line and shale base lines are constructed. Sand grain size can be calibrated with the S.P. curve where cores or well cuttings are available.

- **We discuss the methods which may be used to interpret the depositional environment of sediments in the sub-surface. The key to the sub-surface diagnosis of terrigenous rocks lies in the study of vertical sequences: Only two aspects of formation evaluation**
- **1- Interpretation of vertical grain-size profiles by use geophysical logs**
- **The two logs which are mainly used as grain-size profiles are the Spontaneous Potential (generally abbreviated to S.P.) and Gamma logs.**



our characteristic gamma log motifs. From left to right: thinly interbedded sand and shale; an upward coarsening profile with an abrupt upper sand: shale contact; a uniform sand with abrupt upper and lower contacts; and, furthest right, an upward fining sand: shale sequence with an abrupt base. None of these motifs is environmentally diagnostic on its own. Coupled with data on their glauconite and carbonaceous detritus content, however, they define the origin of many sand bodies.

Interpretation of vertical grain-size profiles by use geophysical logs



- Grain size profiles and gamma log responses for some upward-fining sequences. Note how intraformational conglomerate on a channel floor may cause
- the gamma log to apparently indicate an upward-coarsening sequence.
- Thus the wireline log can be calibrated with real and they can be supplementary core and palaeontological data

		Marine	Non-marine
		Glauconite and/or shell debris	No glauconite or shell debris
Well winnowed	Not carbonaceous detritus or mica	barrier, bar, shoal } marine shelf sands	eolian
Poorly winnowed	Cabonaceous and/or micaceous	submarine channel and fan	fluvial, lacustrine, deltaic

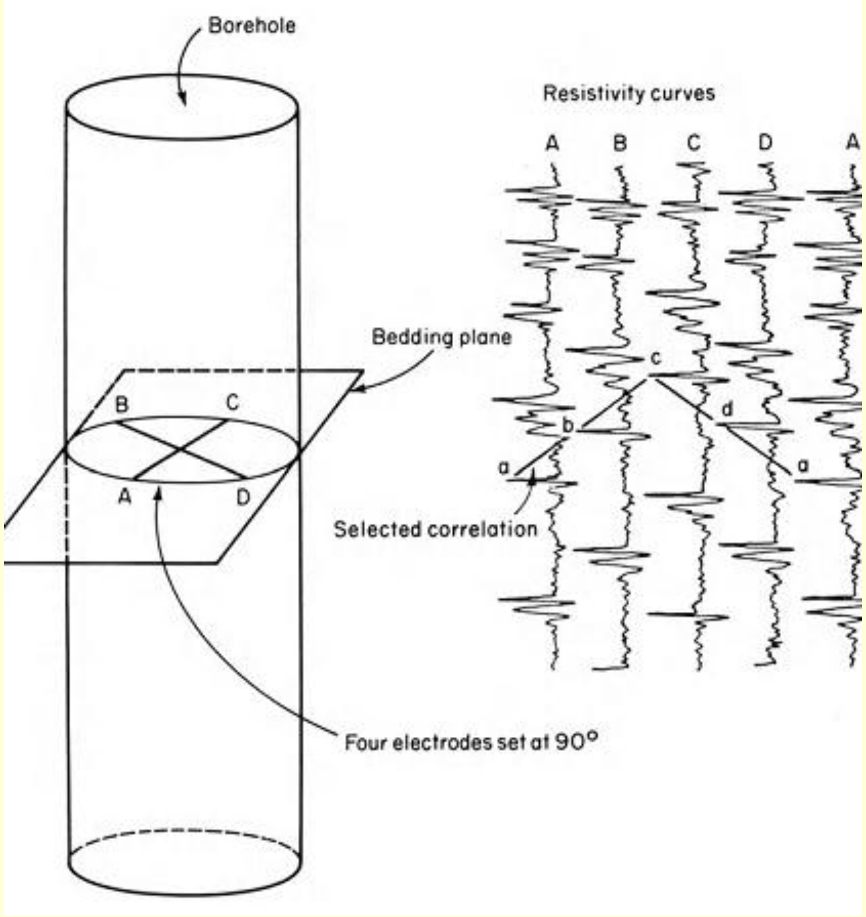
The presence or absence of glauconite and carbonaceous detritus divides sands into four main environmental groups: marine winnowed sands, non-marine winnowed sands (eolian), mixed sands with both glauconite and carbonaceous matter, commonly found as turbidites, and poorly winnowed non-marine sands

Where these are absent and the occurrence of glauconite, shell debris, mica and carbonaceous detritus can be used to assist in the correct identification of log motifs

The glauconite is used as an indicator of a marine environment

Mica is generally winnowed out of high energy environments and tends to be deposited in low energy ones

The use of the dipmeter in sub-surface facies analysis



Sketch to show the mode of operation of the dipmeter log and the way in which dip directions are calculated from the four mutually opposed resistivity curves.

- **A technique in sub-surface facies analysis is the interpretation of sedimentary dips from the dipmeter log**
- **The dipmeter tool consists of a sonde with four pairs of closely spaced electrodes at 90° from one another**
- **Simultaneously a recording is made of the orientation of the sonde with respect to the magnetic north**
- **By using resistivity of sediments is very variable, it is possible to calculate the direction and the amount of dip of the surface.**