

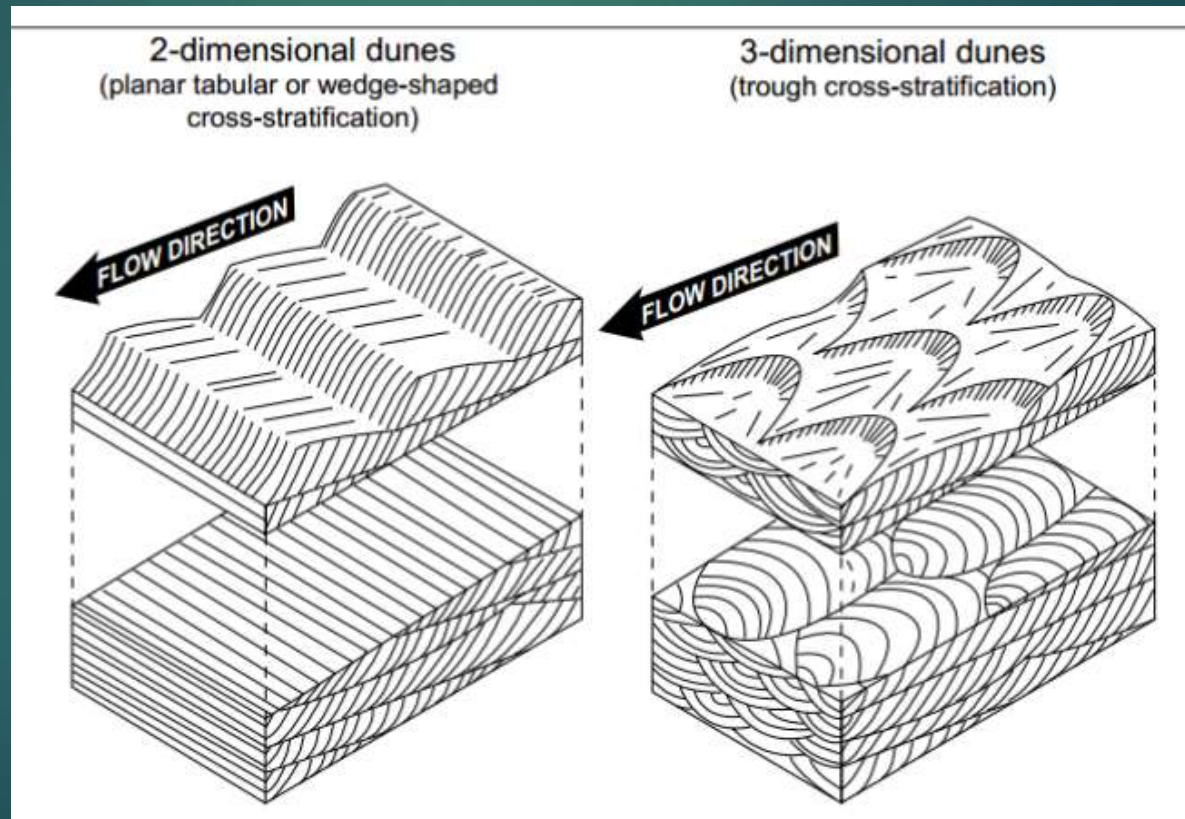


**GGY 4031**  
**LECTURE NOTES 5b**

# SEDIMENTOLOGY

## Cross stratification

- Occurrence of bedding plane exposure of bedforms is relatively rare in outcrop. Because bedforms migrate through each other, observations of internal structure is limited



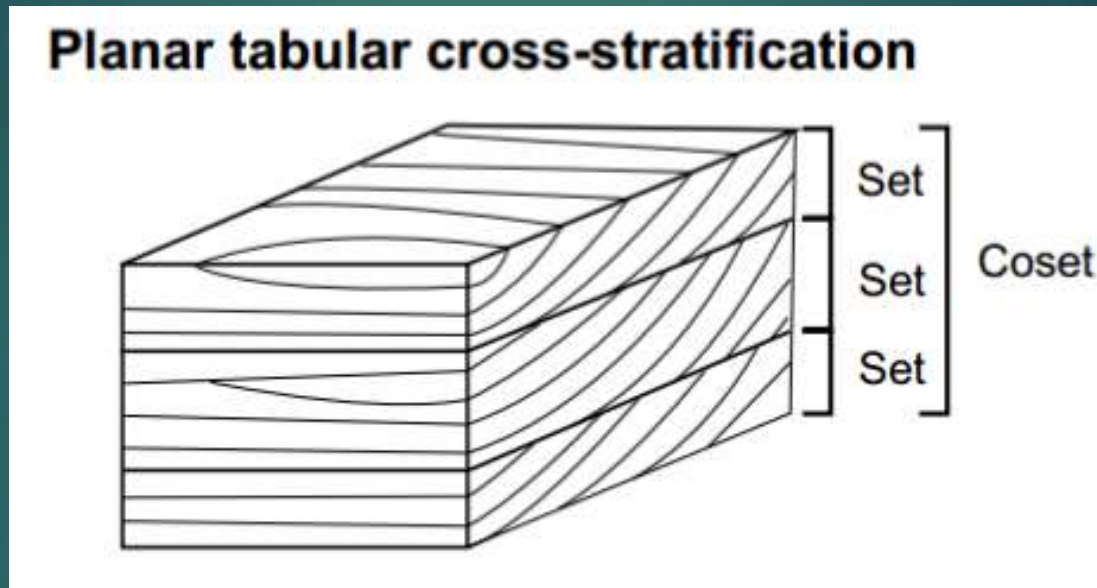
# SEDIMENTOLOGY

## *Cross-stratification*

- All stratification that is inclined due to primary processes (i.e., not tectonic deformation or tilting).
- It includes packages of parallel beds or laminae that are bounded by planar surfaces (bedding planes that are termed bounding surfaces).
- The upper bounding surface is normally an erosional surface and truncates underlying internal strata
- The strata between bounding surfaces are often termed *internal strata or internal stratification*.
- Internal strata are distinguishable as stratification on the basis of often subtle changes in *grain size* and/or *mineralogical composition*.

# SEDIMENTOLOGY

- A group of similar internal cross-strata, between bounding surfaces, is referred to as a cross-strata set; a group of similar sets of cross-strata is referred to as a coset



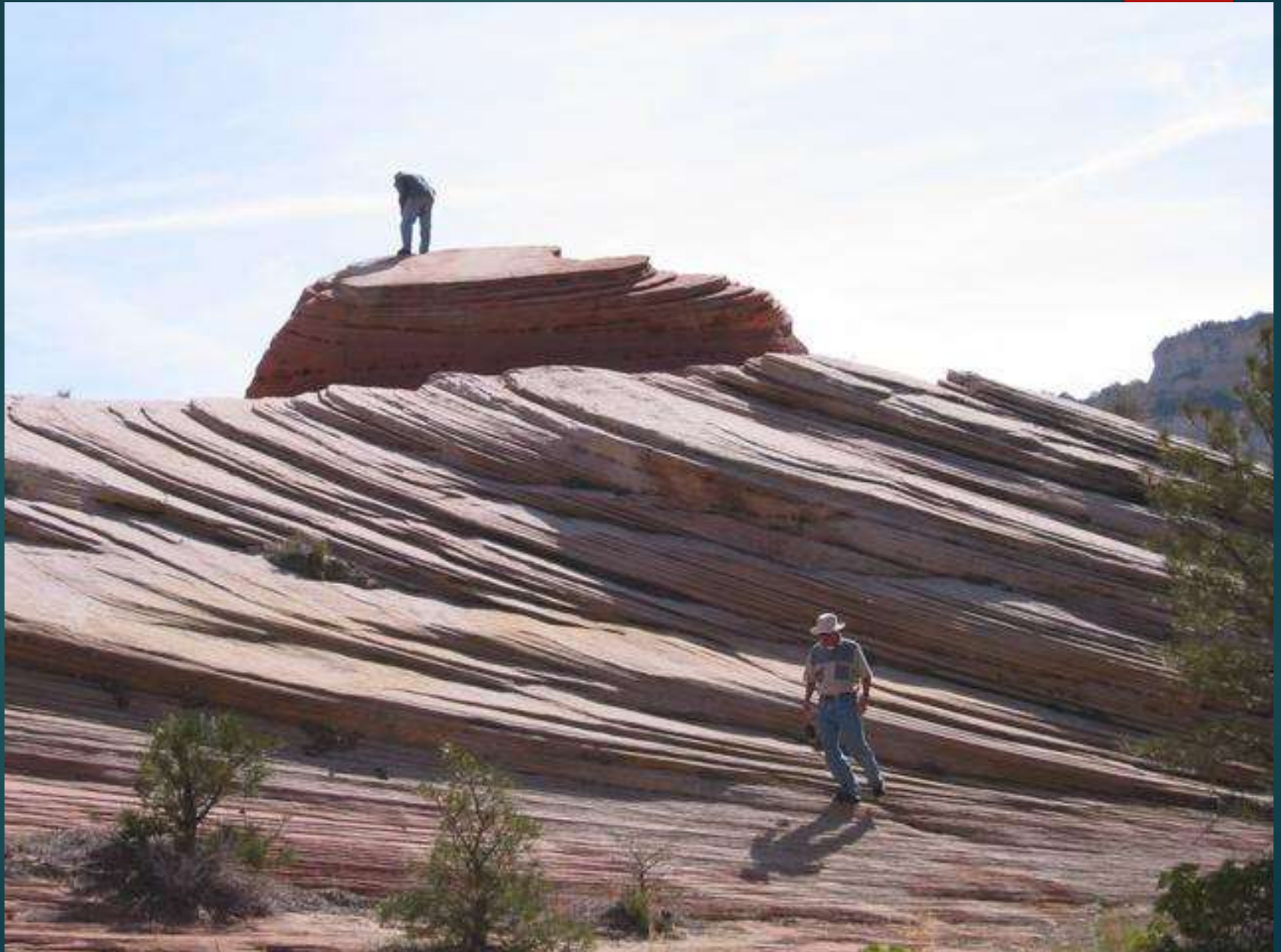
Cross stratification can be classified as either

- *Cross lamination*: layers are only a few mm
- *Cross bedding*: larger layers

# SEDIMENTOLOGY



# SEDIMENTOLOGY



# SEDIMENTOLOGY



# SEDIMENTOLOGY

## *Nature of cross stratification*

- arranged as sets of conformable laminae, planar or curving, that are separated from adjacent sets by erosional set boundaries or *truncation surfaces*
- Cross beds always dip down in the direction towards which the water or air was flowing
- The slope of the foreset beds are a function of the grain size of the sediments. Coarse (sand and gravel) sediments will give steep slopes, while fine sediments (fine sand and silt) will give shallow slopes.
- Cross bed angles shallow in the down-flow direction, giving a tangential contact with the underlying bed. These nearly tangential parts are called *bottom sets*.

# SEDIMENTOLOGY



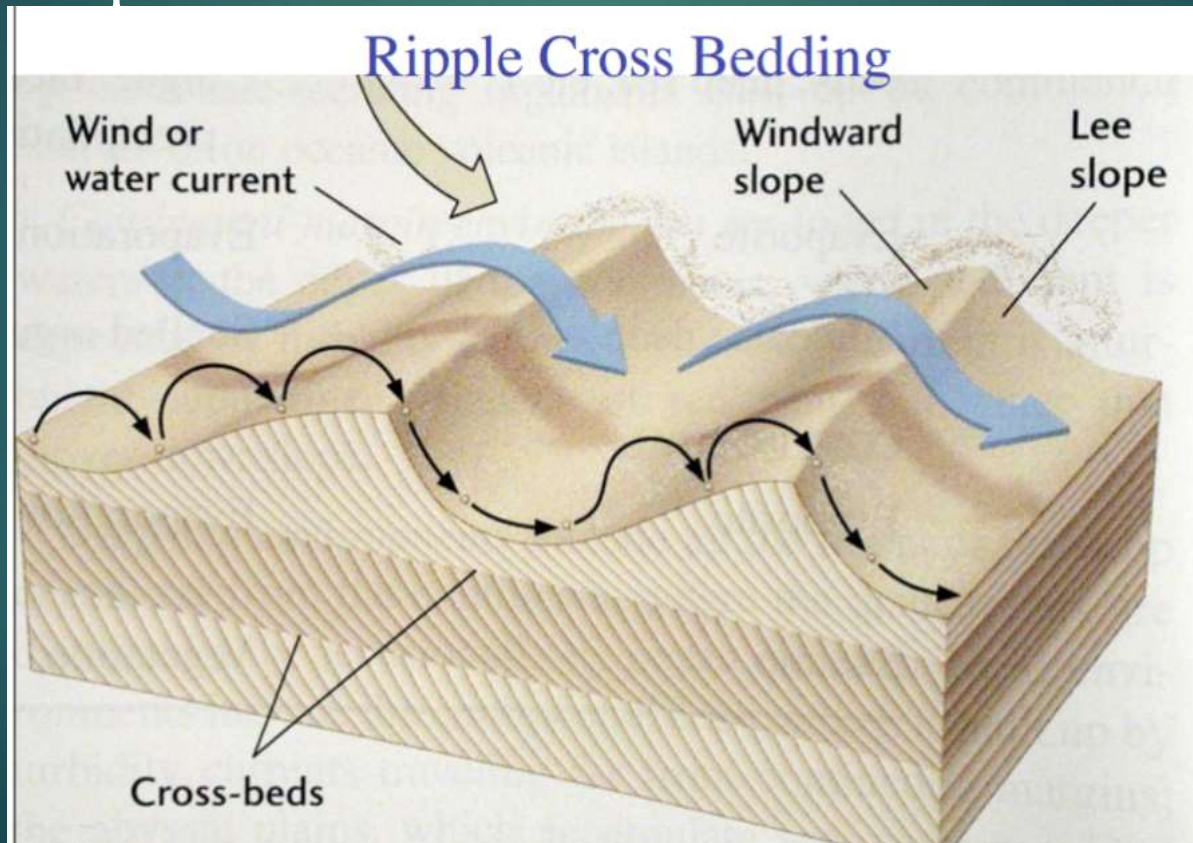
Truncation  
Surfaces



# SEDIMENTOLOGY

## Cross-bedding/lamination:

- forms primarily by migration of ripples and dunes in water or air leading to formation of dipping foreset laminae owing to avalanching or suspension settling in the zone of separation on the leesides of these bedforms



# SEDIMENTOLOGY

## Tabular cross-bedding/lamination

- consists of cross-bedded/laminated units that are broad in lateral dimensions with respect to set thickness, and that they have essentially planar bounding surfaces

- Tabular cross-bedding is formed mainly by the migration of large-scale, straight-crested ripples and dunes



# SEDIMENTOLOGY

*Trough cross bedding*- consists of cross-bedded units in which one or both bounding surfaces are curved.

- originate both by migration of small sinuous crested current ripples, which produces small-scale cross-bed sets, OR by migration of large-scale, trough-shaped dunes



**Curved, Tangential foresets**

# SEDIMENTOLOGY

**Flaser bedding**: ripple bedding in which thin streaks of mud occur between sets of cross-laminated or ripple laminated sandy or silty sediment. More sand than mud.



# SEDIMENTOLOGY



## In Flaser bedding:

- Mud is concentrated mainly in the ripple troughs but may also partly cover the crests.
- *Flaser bedding* suggests deposition under fluctuating hydraulic conditions. Periods of current activity, when traction transport and deposition of rippled sand take place, alternate with periods of quiescence, when mud is deposited

# SEDIMENTOLOGY

**Lenticular Bedding**: a structure formed by interbedded mud and ripple cross-laminated sand in which the ripples or sand lenses are discontinuous and isolated in both a vertical and horizontal direction. More mud than sand.



# SEDIMENTOLOGY



## NOTE:

*Flaser bedding* is produced in environments in which conditions for deposition and preservation of sand are more favorable than for mud

*Lenticular bedding* is produced in environments in which conditions favor deposition and preservation of mud over sand.

# SEDIMENTOLOGY

## Hummocky cross-stratification

- characterized by undulating sets of cross-laminae that are both concave-up (swales) and convex-up (hummocks)

### HUMMOCKY CROSS STRATIFICATION - HCS

LONG WAVELENGTH, 1 - 5 M  
LOW HEIGHT, FEW 10'S OF CM  
HUMMOCKS AND SWALES CIRCULAR TO ELLIPTICAL IN PLAN VIEW

INDIVIDUAL SSTs. AVERAGE  
SEVERAL 10'S OF CM.

LAMINATIONS DRAPE  
HUMMOCKY SURFACE

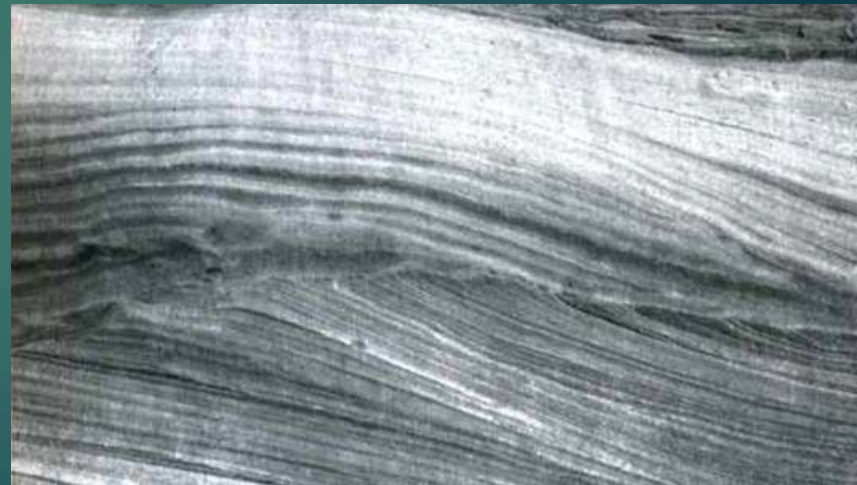
SHARP BASE; IN PLACES,  
DIRECTIONAL SOLE MARKS

LOW ANGLE CURVED  
LAMINA INTERSECTIONS,  
AS HUMMOCKS AND SWALES  
MIGRATE SLIGHTLY

SSTs. COMMONLY INTERBEDDED  
WITH BIOTURBATED MSTs.

HCS CHARACTERIZED BY -

- 1, UPWARD CURVATURE OF LAMINATIONS
- 2, LOW ANGLE, CURVED LAMINA INTERSECTIONS
- 3, VERY LONG WAVELENGTHS, LOW HEIGHTS;  
LAMINA DIPS NORMALLY LESS THAN 10°



# SEDIMENTOLOGY



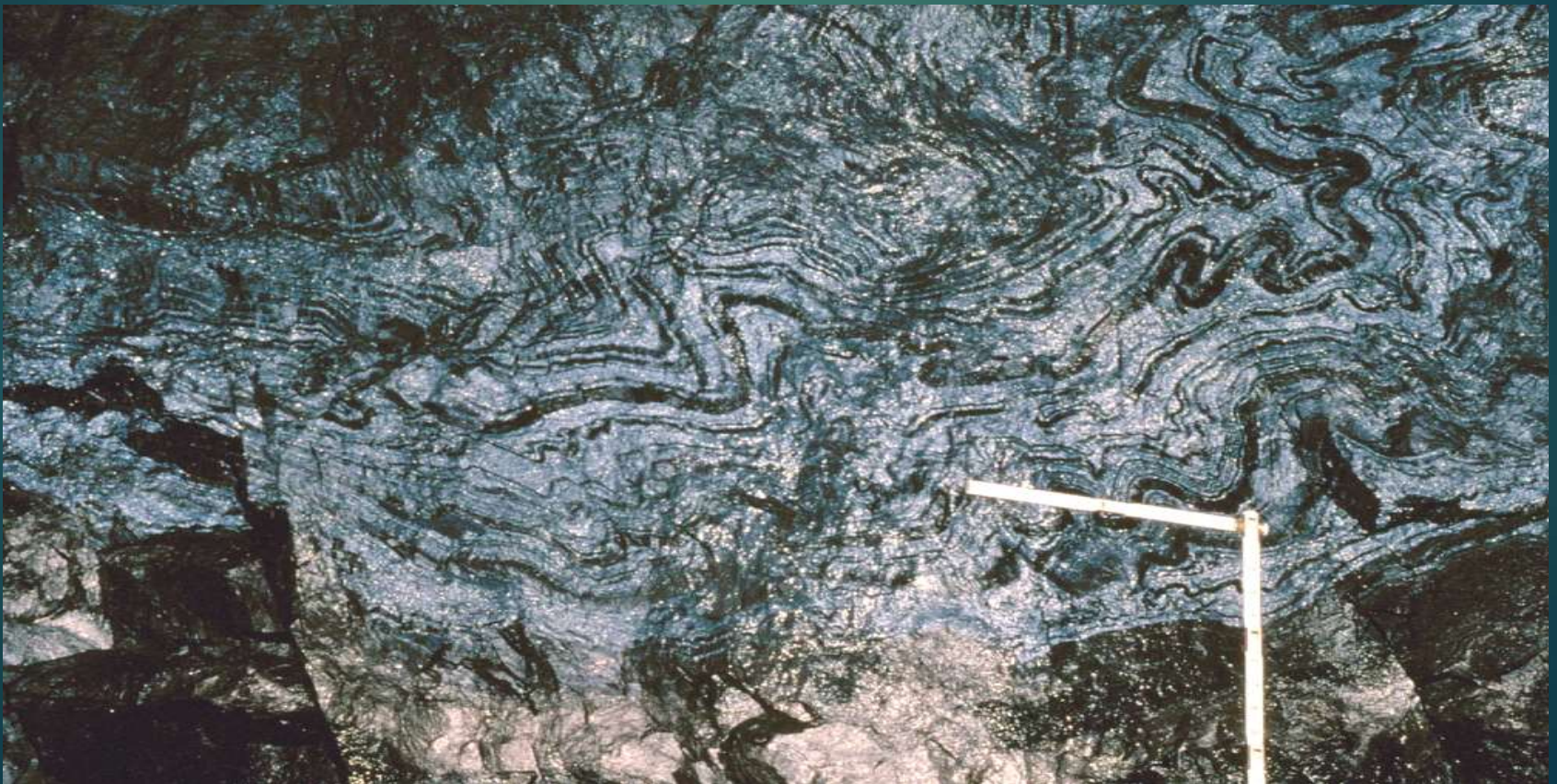
## *Significance of Cross Stratification*

- Strongly reflects velocity of transporting medium
- Dip direction of cross strata reflects sediment transport direction

# SEDIMENTOLOGY

## Irregular Stratification

Convolute bedding and lamination: a structure formed by complex or intricate crumpling of beds or laminations into irregular, generally small-scale anticlines and synclines.



# SEDIMENTOLOGY

**Flame Structures**: wavy flame-shaped tongues of mud that project upward into an overlying layer, which is commonly sandstone.



# SEDIMENTOLOGY

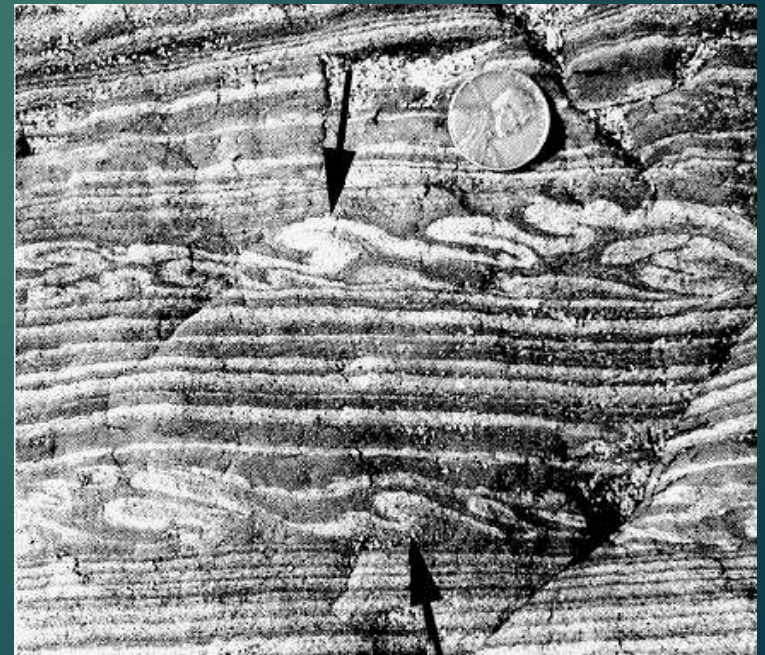
**Ball and pillow structures**: present in the lower part of sandstone beds and less common in limestone beds, that overlie shales. They consist of hemispherical or kidney-shaped masses that show internal laminations.



# Synsedimentary Folds and Faults (slump structures)



Décollement structure



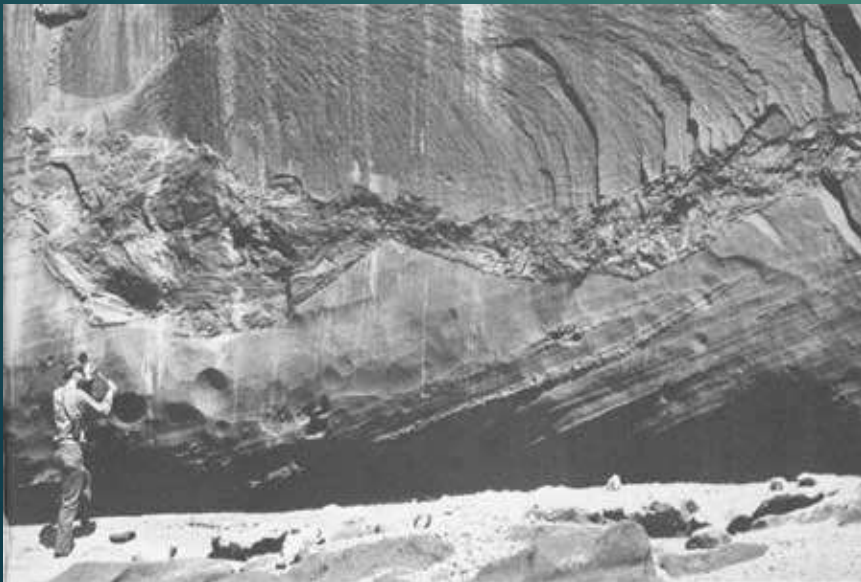
# Convolute lamination



# Dish and pillar structures



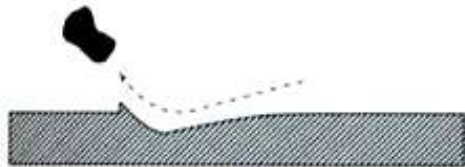
# Scour and fill structures



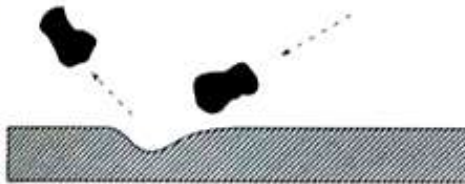
# Bedding-plane markings



**A** Bounce marks. The tool approaches the sediment surface at a low angle and immediately bounces back into the current.



**B** Brush marks. The tool approaches the sediment surface at a very low angle, with the axis of the tool inclined upcurrent, and is then lifted away by the current, producing a ridge of mud downcurrent of the mark.



**C** Prod marks. The tool reaches the sediment surface at a fairly high angle and is then lifted up and away by the current.



**D** Roll marks. The tool rolls over the sediment surface, producing a continuous roll mark.

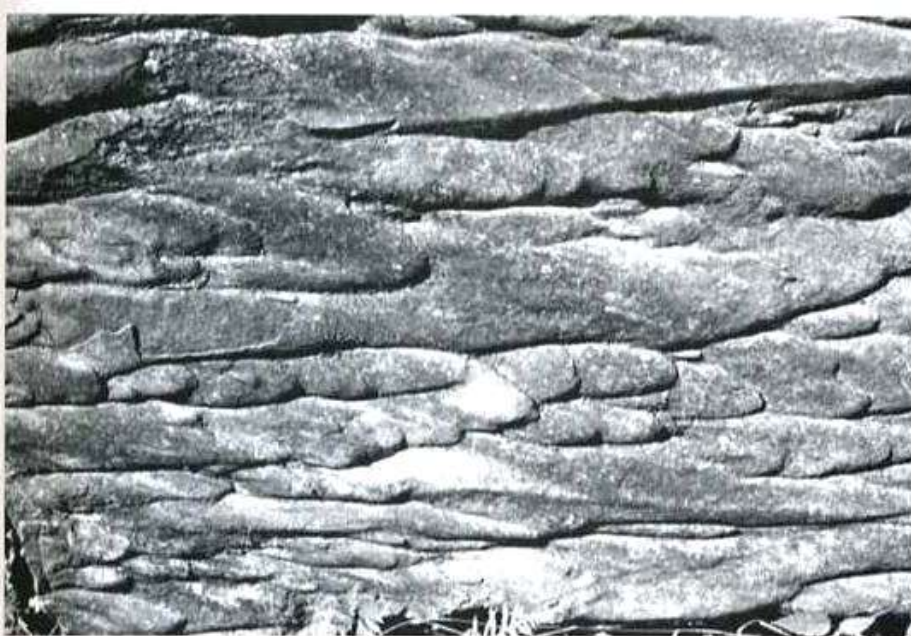


**E** Skip marks. The tool travels downcurrent with a saltating movement, hitting the sediment surface at nearly regular intervals.

**Figure 4.35**

Development in a cohesive mud bottom of (A) bounce marks, (B) brush marks, (C) prod marks, (D) roll marks, and (E) skip marks by action of "tools" making contact with the bottom in various ways. These tool-formed depressions are subsequently filled with coarser sediment to produce positive-relief casts. [After Reineck, H. E., and I. B. Singh, 1980, *Depositional sedimentary environments*, 2nd ed., Fig. 127, 129, 125, 132, p. 82, 83, reprinted by permission of Springer-Verlag, Heidelberg.]

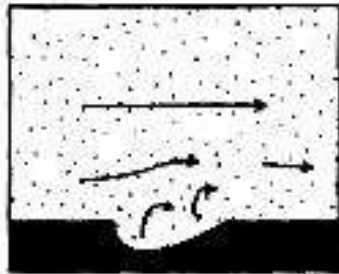
# Groove and Flute casts



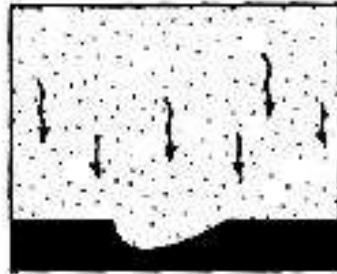
**Figure 4.36**

Flute casts on the base of a turbidite sandstone, Fluornoy Formation (Eocene), Oregon Coast Range. The bulbous terminations of the flute casts indicate that paleocurrent flow was from right to left. [Photograph courtesy of Ewart Baldwin.]

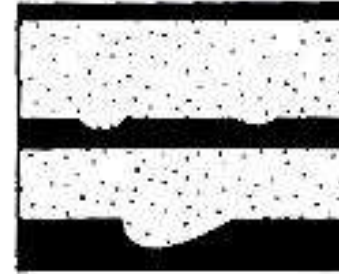
*Sole markings:* owing to erosion of a mud bottom followed by the deposition of coarser material.



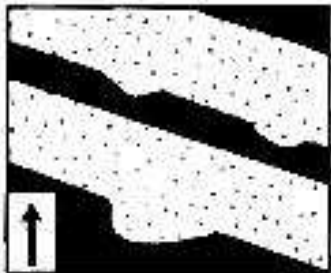
Erosion of bed



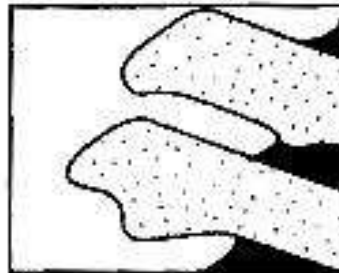
Deposition



Burial and lithification



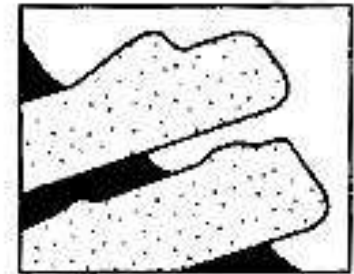
Tectonic tilting



Subaerial erosion



Tectonic overturning



Subaerial erosion

# SEDIMENTOLOGY

## SHRINKAGE CRACKS

Two types are distinguished:

### *Dessication cracks (mudcracks):*

- formed when muds are exposed to drying and shrink due to evaporation of large volume of interstitial water and crack into polygons of wide range of sizes.
- Mudcracks are most visible when they are filled by overlying sediment that is different. They thin downwards to a point and therefore can be good way-up indicators.

# SEDIMENTOLOGY

## MUDCRACKS



# SEDIMENTOLOGY

- Syneresis cracks (also known as subaqueous shrinkage cracks) are a sedimentary structure developed by the shrinkage of sediment without desiccation. Usually there is no pattern to the cracks, and are discontinuous, they do not connect to form geometric shapes

Syneresis cracks are shaped in one of the following categories:

- Polygonal - a closed plane figure, having three or more, usually straight, sides.
- Sinuuous - having many curves, bends, or turns.

# SEDIMENTOLOGY

- Syneresis cracks



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# SEDIMENTOLOGY

## DESSICATION VS. SYNERESIS CRACKS

- Desiccation mudcracks are usually continuous, polygonal, and have U- or V- shaped cross sections that would have been filled in with sediment from above.
- Syneresis cracks, however, are usually discontinuous, spindle or sinuous in shape, and have U- or V- shaped cross sections that have been filled in with sediment from above or below

# SEDIMENTOLOGY

## TRACE FOSSILS

Trace Fossils also known as (ichnofossils) are tracks, trails, burrows burrows and borings and other structures made by organisms on bedding surfaces or with the beds. They are not truly bodily preserved fossils, rather they are structures that originated through activities of living organisms

- Resting traces: shallow surface depressions made by organisms settling temporarily on the substrate
- Crawling traces: tracks or trails produced on the substrate by animals in motion

# SEDIMENTOLOGY

























- Surface grazing traces- tracks or trails produced on the substrate by animals extracting food from the surface of the sediment (analogous to strip mining).
- Burrow-feeding traces— obtaining food from the sediment by mining beneath the surface: entrances to burrows result in surface marking
- Dwelling traces— more or less permanently inhabited burrows beneath the surface, many with surface openings

# Trace Fossils

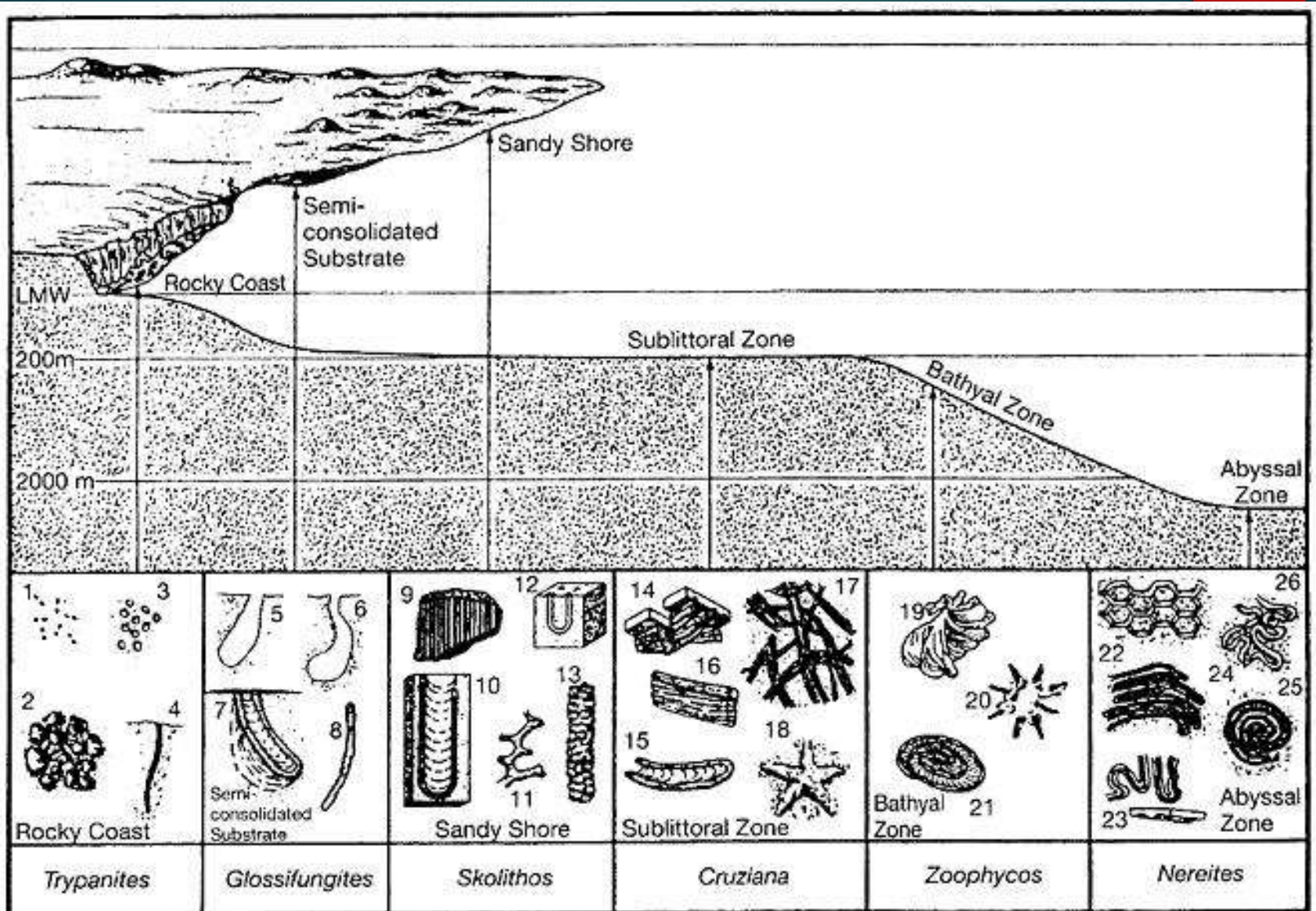


Pamela Gore 1996

# Index Fossils

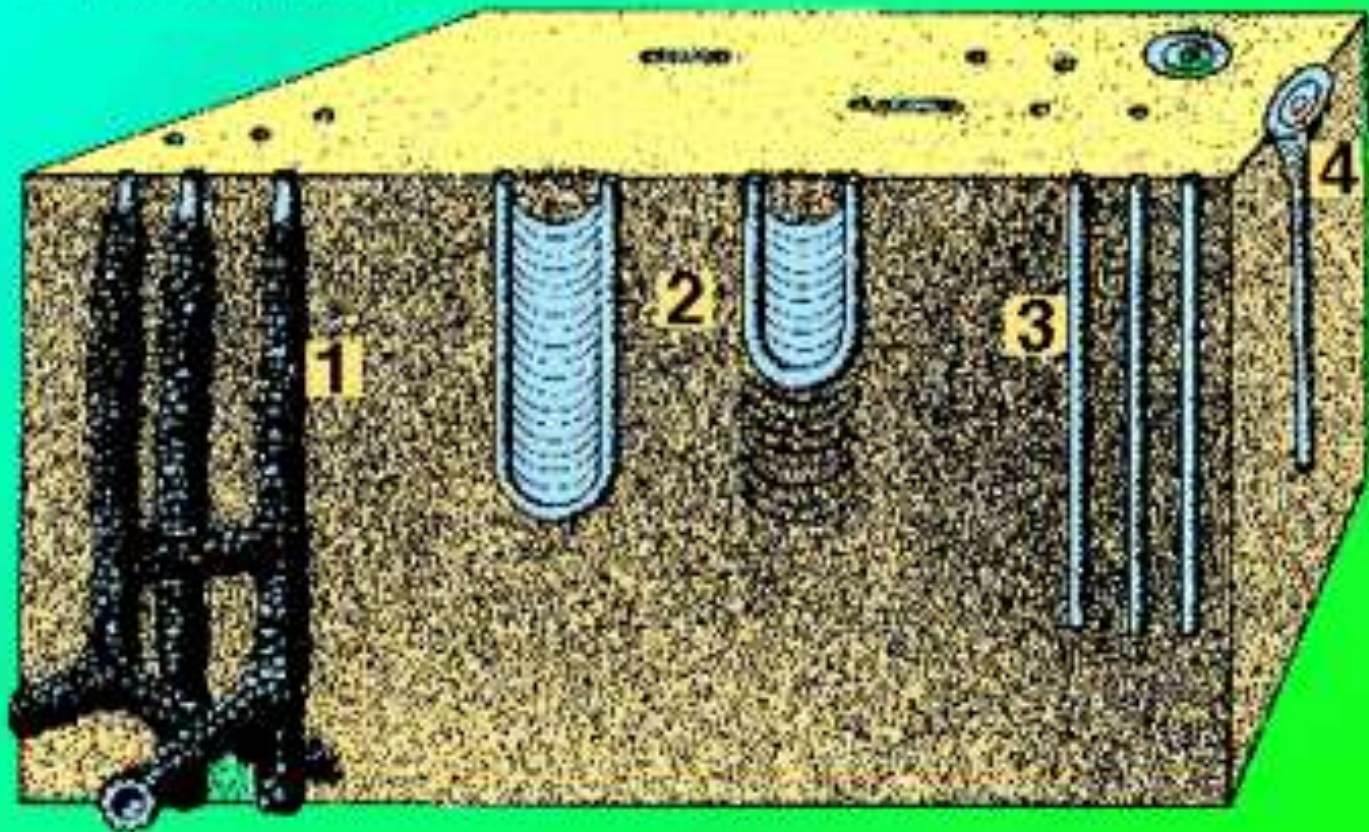
CENOZOIC ERA (Age of Recent Life)	Quaternary Period	<i>Pecten gibbus</i>		<i>Neptunea tabulata</i>		
	Tertiary Period		<i>Calyptrophorus velatus</i>		<i>Venericardia planicosta</i>	
MESOZOIC ERA (Age of Medieval Life)	Cretaceous Period	<i>Scaphites hippocrepis</i>		<i>Inoceramus labiatus</i>		
	Jurassic Period		<i>Perisphinctes tiziani</i>		<i>Nerinea trinodosa</i>	
	Triassic Period	<i>Trophites subbullatus</i>		<i>Monotis subcircularis</i>		
PALEOZOIC ERA (Age of Ancient Life)	Permian Period		<i>Leptodus americanus</i>		<i>Parafusulina bosei</i>	
	Pennsylvanian Period	<i>Dictyoclostus americanus</i>		<i>Lophophyllidium proliferum</i>		
	Mississippian Period		<i>Cactocrinus multibrachiatus</i>		<i>Prolecanites gurleyi</i>	
	Devonian Period	<i>Mucrospirifer mucronatus</i>		<i>Palmatolepus unicornis</i>		
	Silurian Period		<i>Cystiphyllum niagarensis</i>		<i>Hexamoceras hertzeri</i>	
	Ordovician Period	<i>Bathyrurus extans</i>		<i>Tetragraptus fructicosus</i>		
	Cambrian Period		<i>Paradoxides pinus</i>		<i>Billingsella corrugata</i>	
	PRECAMBRIAN	-----				

# Schematic representation of the relationship of the characteristic trace fossils to sedimentary faces and depth zones in the ocean.

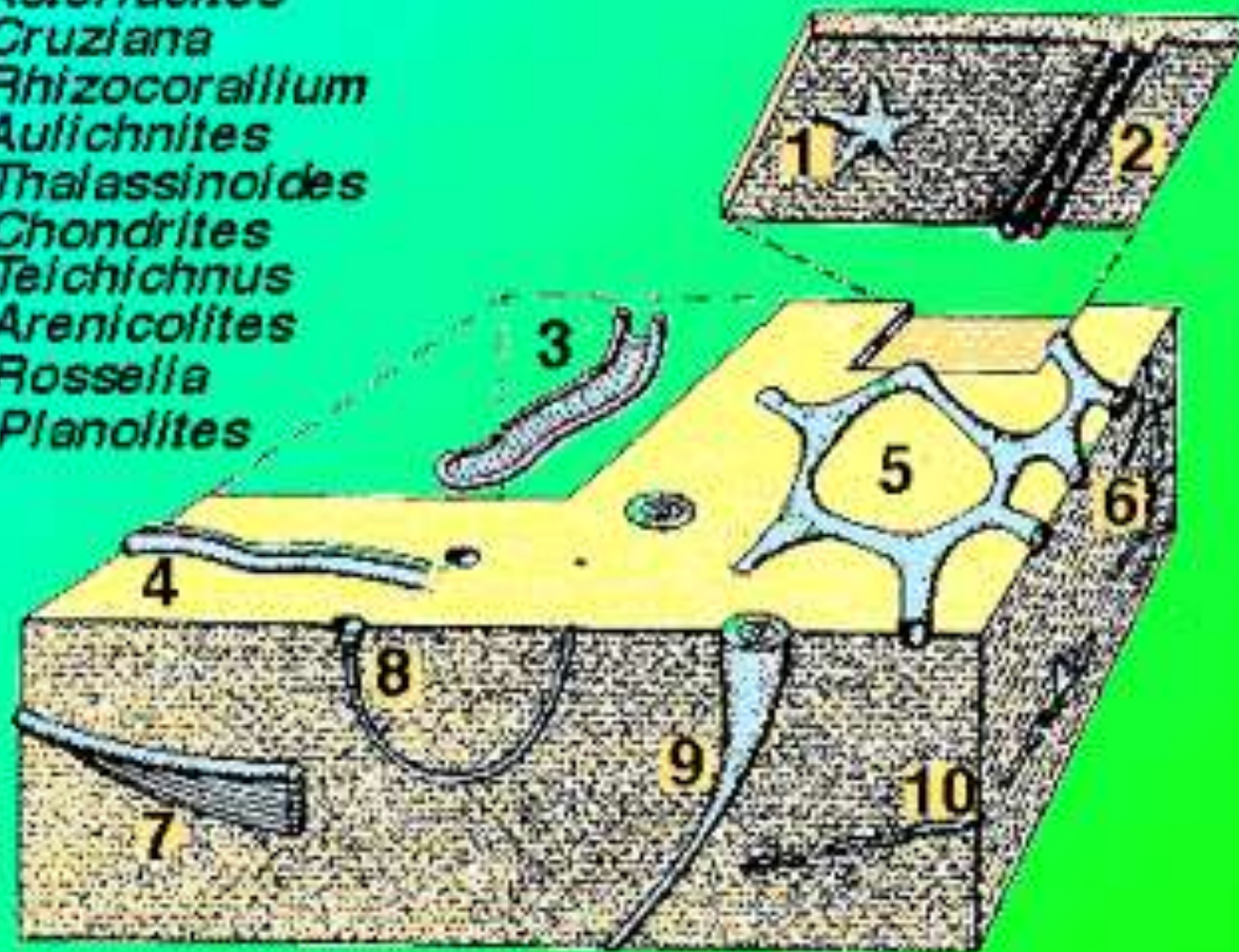


1. *Ophiomorpha*
2. *Diplocraterion*
3. *Skolithos*
4. *Monocraterion*

## Skolithos ichnofacies



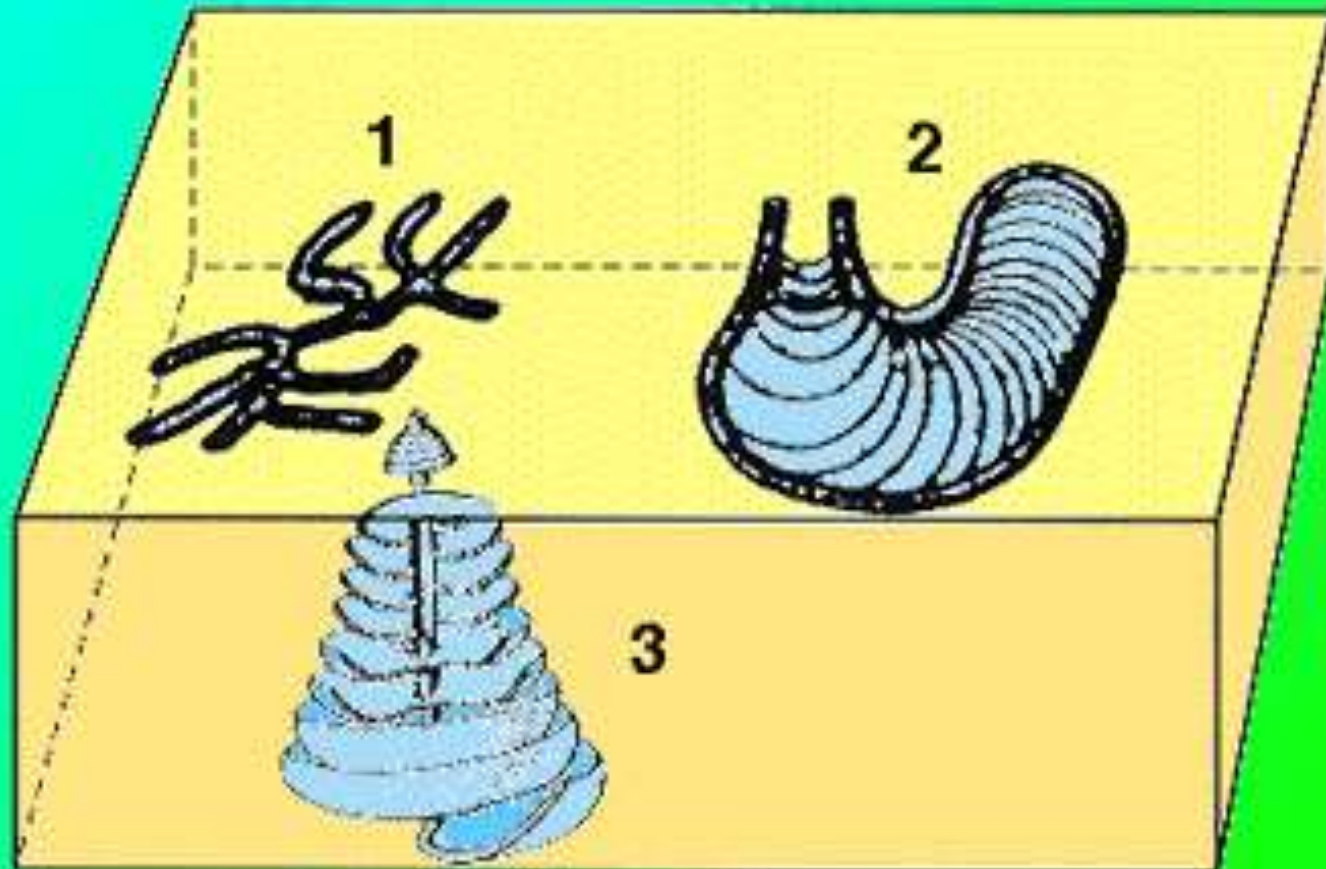
1. *Asteriacites*
2. *Cruziana*
3. *Rhizocorallium*
4. *Aulichnites*
5. *Thalassinoides*
6. *Chondrites*
7. *Teichichnus*
8. *Arenicolites*
9. *Rosselia*
10. *Planolites*



**Cruziana Ichnofacies**

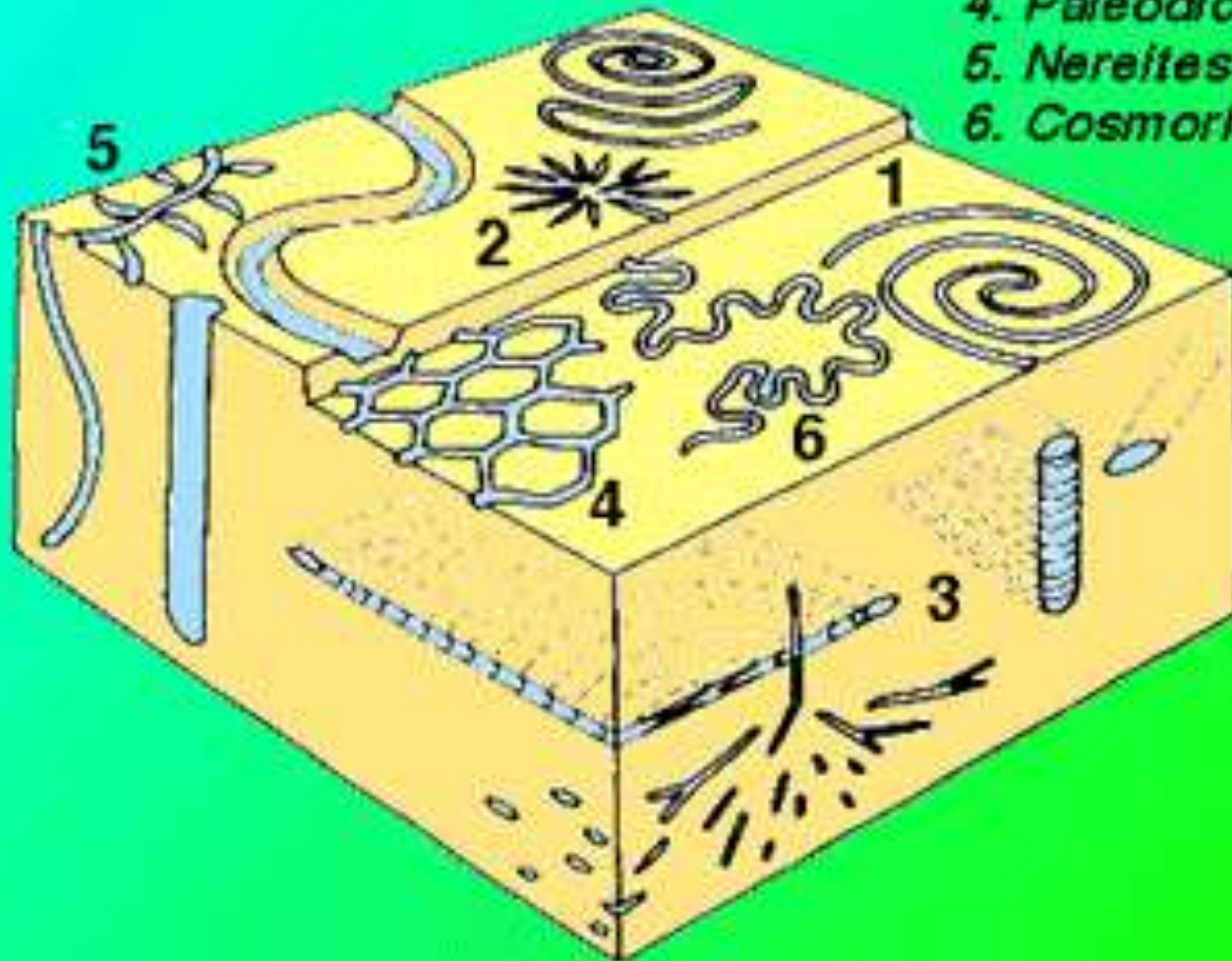
## Zoophycos Ichnofacies

1. *Phycosiphon*
2. *Zoophycos*
3. *Spirophyton*



## Nereites Ichnofacies

1. *Spiroraphe*
2. *Lorenzinia*
3. *Chondrites*
4. *Paleodictyon*
5. *Nereites*
6. *Cosmorhaphe*



# SEDIMENTOLOGY

## SIGNIFICANCE OF TRACE FOSSILS

- Interpretations of paleo-environment
- Different types of activities are characteristics of different sedimentary environment (different depth, types of substrates, oxygen levels, etc..)
- Distinguish supratidal, intertidal, shallower subtidal and deeper subtidal marine environment

**Stromatolites**: organically formed laminated structures composed of fine silt or clay-sized sediment, or more rarely, sand-size sediment.



