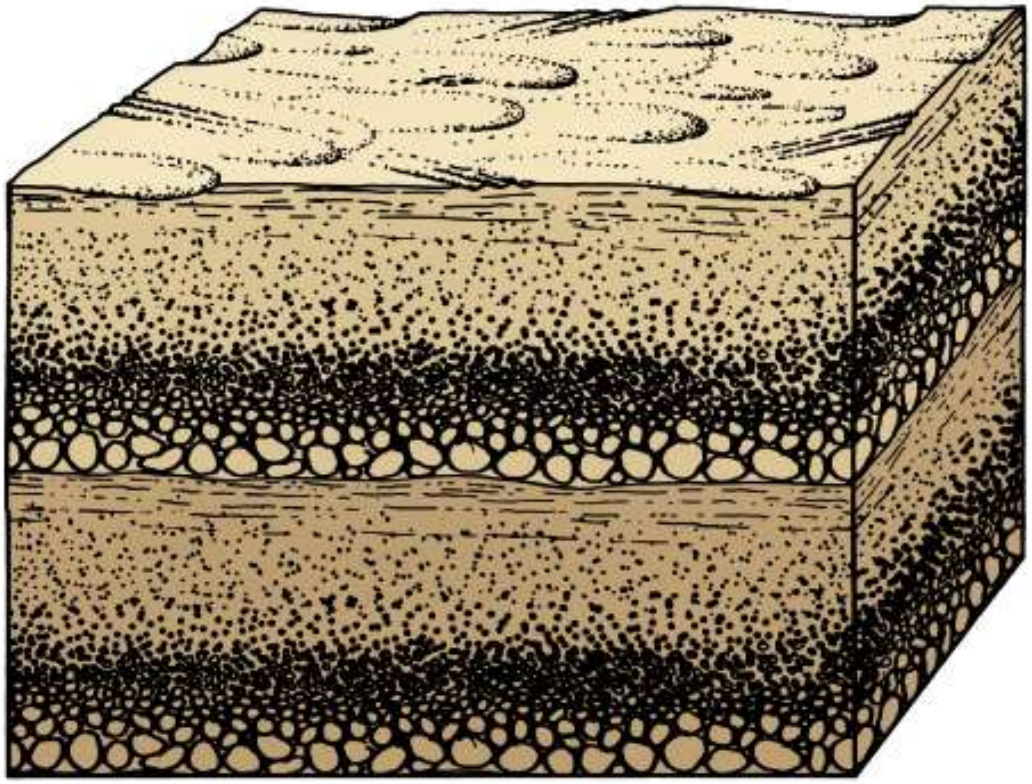
GGY 4031
LECTURE NOTES 4a

SEDIMENTOLOGY

Graded Bedding (normal grading) – Which way is up?



SEDIMENTOLOGY

A bedform: a morphological feature formed by the interaction between a flow and cohensionless sediment on a bed

Classification of Bedforms

- By flow regimes such as:

✓ Lower flow regimes

✓ Upper flow regimes

The size and shape of bed forms depend on the flow velocity, flow depth, ***Froude number,*** stream power

SEDIMENTOLOGY

I) Froude Number (F_r):

- ✓ explains how a fluid transmits surface waves, and is related to the forces that act on a moving fluid
- ✓ A ratio of inertial force (related to mass, velocity) to gravitational forces (related to g, depth):

$$F_r = \frac{U}{\sqrt{gL}}$$

Where:

F_r = Froude number

U = mean flow velocity

g = acceleration due to gravity

L = water depth

SEDIMENTOLOGY

If $F_r < 1$, waves can move upstream
This is called the ***Lower flow regime,*** and flow is described as:

- ✓ Tranquil
- ✓ Streaming
- ✓ Subcritical flow

If $F_r > 1$, waves can't move upstream
This is called the ***Upper flow regime,*** and flow is described as:

- ✓ Rapid
- ✓ Shooting
- ✓ Supercritical

SEDIMENTOLOGY

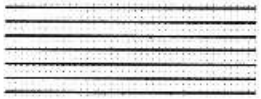
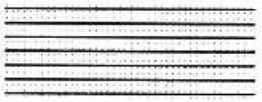
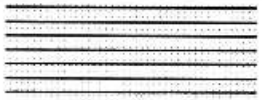
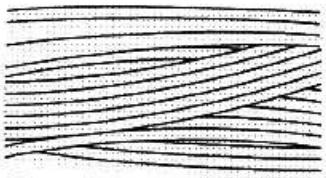
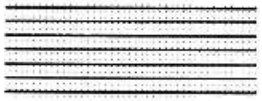
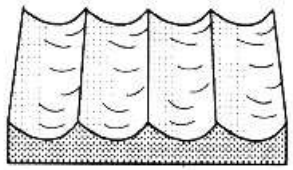
Flow Regime	Bedforms	Characteristics
Lower flow regime	Lower plane bed, Ripples, Dunes	• $\mathbf{F} < 0.84\text{-}1.0^{*}$; • low rate of sediment transport, dominated by contact load; • bedforms out-of-phase with the water surface.
Upper flow regime	Upper plane bed, In-phase waves, Chutes and pools	• $\mathbf{F} > 0.84 - 1.0^{*}$; • high rates of sediment transport, high suspended load; • bedforms in-phase with the water surface.

*Note that Simons and Richardson (1961) set $\mathbf{F} < 1.0$ for lower flow regime and $\mathbf{F} > 1.0$ for upper flow regime. However, subsequent work indicated that in-phase waves began to develop over the range $0.84 < \mathbf{F} < 1.0$. Because in-phase waves were particularly characteristic of the upper flow regime the limiting value of **F** has been adjusted accordingly here.

SEDIMENTOLOGY

Sedimentry Structures
RESULTING FROM CHANGES IN FLOW ENERGY AND FLOW DIRECTION

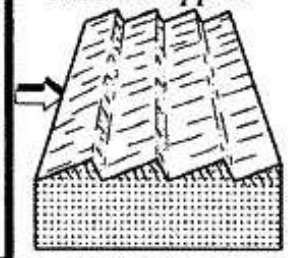
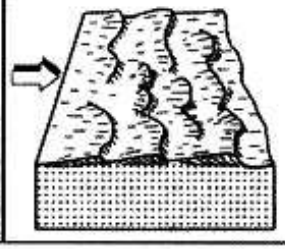
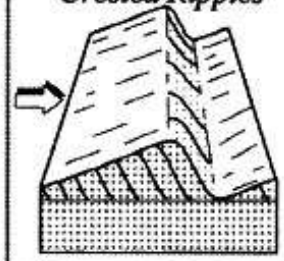
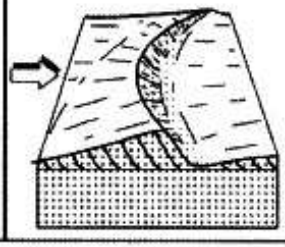
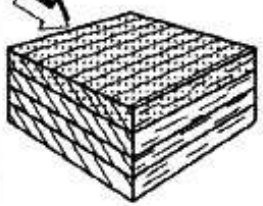
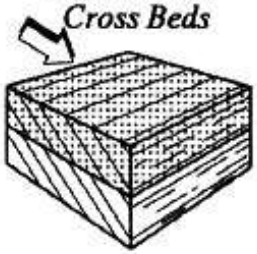
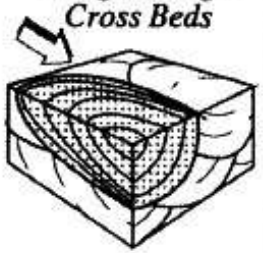
Flow Energy of Environment: High ↑ Low

UNIDIRECTIONAL FLOW DIRECTION ←	*COMBINED-FLOW DIRECTION* ← →	*OSCILLATION FLOW DIRECTION* ↔
Water flows constantly in one direction–for example, a river.	Oscillation flow with a superposed unidirectional flow–for example, shelf waves plus a storm current.	Wave energy fluctuates water back and forth–for example, a wave-washed beach or tidal flat.
 Upper flow regime high-velocity laminations (side view)	 upper flow regime high-velocity laminations (side view)	 upper flow regime high-velocity laminations (side view)
Upper–Lower flow regime straight-crested and lunate ripples and their cross beds. See the table on previous page.	 Upper–lower flow regime hummocky cross stratification (side view as seen in rock)	 Upper–lower flow regime plane bed (side view as seen in rock)
Lower–lower flow regime straight-crested linguloid ripples and their cross beds. See the table on previous page.	 Lower–lower flow regime climbing ripples (side view as seen in rock)	 Lower–lower flow regime symmetrical (oscillation) ripples

SEDIMENTOLOGY

FLOW REGIME DIVISIONS AND RESULTING SEDIMENTRY STRUCTURES

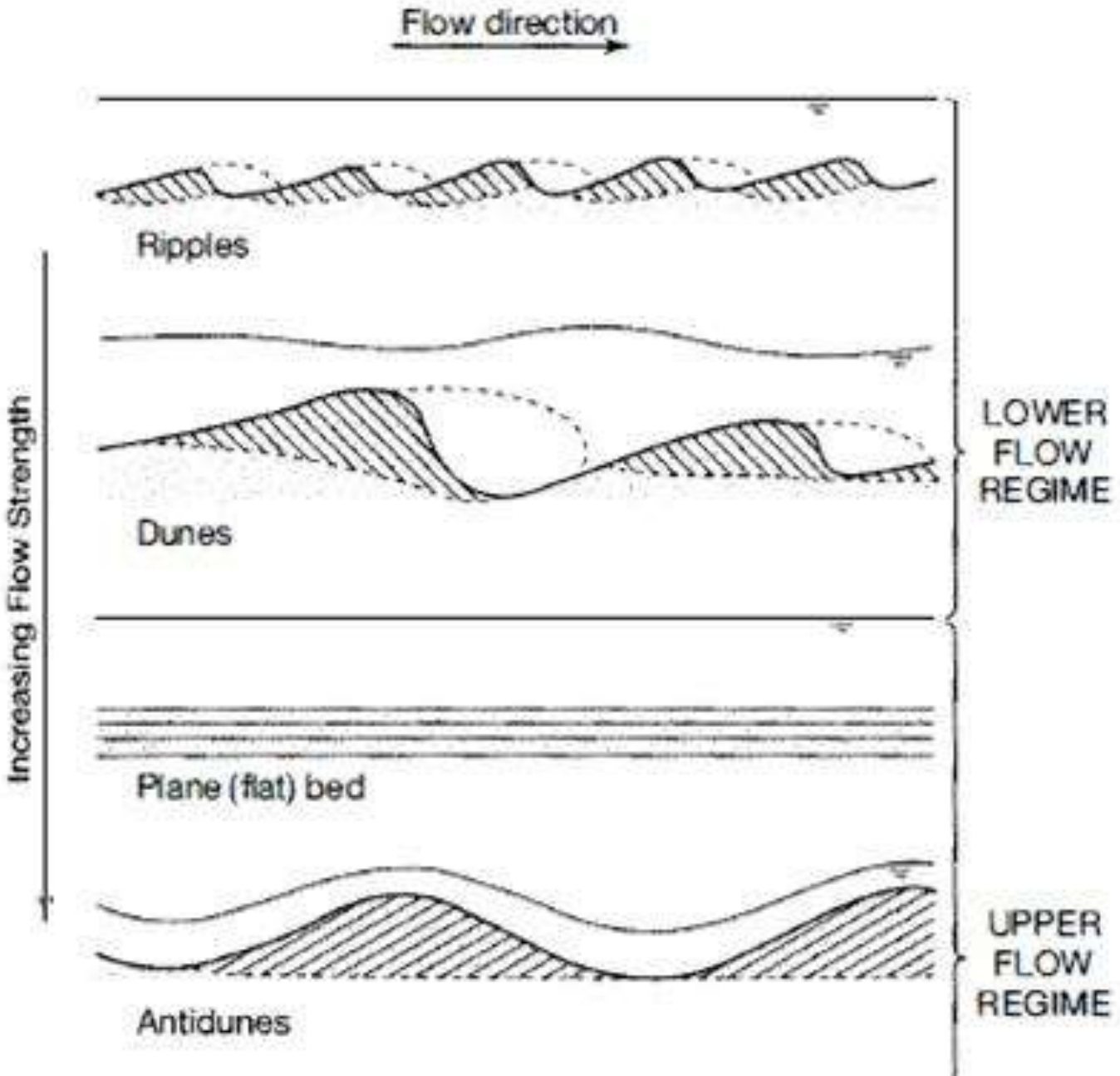
LOW ENERGY → increasing water velocity → **HIGH ENERGY**

	LOWER FLOW REGIME		UPPER FLOW REGIME	NO DEPOSITION; EROSION (All particles in motion)
	Lower–Lower	Upper–Lower		
BED FORMS	**Small Ripples** *Wave length < 30 cm; usually less* Small Straight-Crested Ripples  Linguloid Ripples 	**Large Ripples** *Wave length > 1 meter; no upper limit* Large Straight-Crested Ripples  Lunate Ripples 	Plane Bed and Antidunes	Flute Marks, Scour Channels
INTERNAL STRUCTURES	The following sedimentary structures result from the foregoing bed forms: **Small Cross Beds** *< 5 cm high; usually much less* Small Planar Cross Beds  Small Trough Cross Beds 	**Large Cross Beds** *> 5 cm high; no upper limit* Large Planar Cross Beds  Large Trough Cross Beds 	HVLs (High-velocity laminations)	Sediment Channel Fill (For example, a point-bar sequence)

SEDIMENTOLOGY

Flow Regime (FR)	Bedforms	Sedimentary Structures
No grain movement	flat (parallel) beds	Parallel bedding
lower-lower FR	ripples	cross laminations
lower FR	sand waves (2d)	planar-tabular x-beds
upper-lower FR	dunes (3d)	trough x-beds
lower-upper FR	plane bed	planar beding
upper FR	antidunes	up-current dipping laminations

SEDIMENTOLOGY



SEDIMENTOLOGY

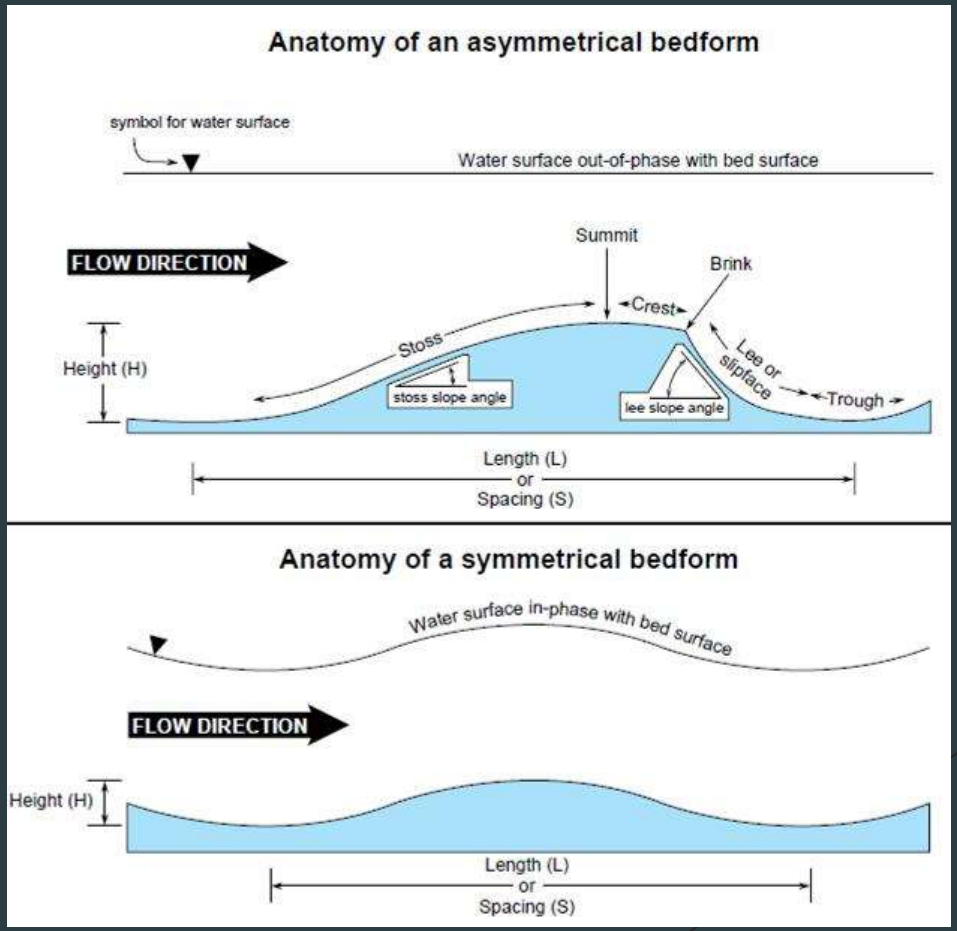
Ripples

- are undulations of the sediment surface produced as wind or water moves across sand (silts and very fine to coarse sands as soon as flow velocity is sufficient for the sediment to be entrained (put into motion).
- Or **Ripples** are dynamic structures that migrate downstream, with sediment being eroded from the gently inclined upstream side and accumulating by avalanching down the steeper downstream face.

NOTE: Ripples which form in unidirectional currents (such as in streams or rivers) tend to be **asymmetrical.** Crests of asymmetrical ripples may be straight, sinuous, or lobe-like (lingoid ripples), depending on water velocity.

SEDIMENTOLOGY

- ***Asymmetrical ripples*** have a gentle slope on the **upstream side**, and a steep slope on the **downstream side**. Because of this unique geometry, asymmetrical ripples in the rock record may be used to determine ancient current directions or paleocurrent directions.



SEDIMENTOLOGY

RIPPLES:

SEDIMENTOLOGY

NOTE:

The sequence of bedforms differs somewhat for sediments of different grain sizes.

- For instance, ripples are not developed in coarse sand and fine gravel
- Also, sand waves and dunes are not developed in silt and very fine sands
- **Asymmetrical ripples** are commonly **water flow-generated bedforms**

SEDIMENTOLOGY

Dunes

- bedform that develop with increasing flow strength beyond the upper limit of ripples. They are similar in form to ripples (i.e., asymmetric bedwaves) but are larger than ripples with lengths ranging from greater than 0.75 m to in excess of 100 m and heights ranging from greater than 0.075 m to in excess of 5 m.
- Dunes tend to be most common on sand beds with a mean size in excess of 0.15 mm.

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Unlike ripples, dune size seems to be not related to the grains size of the bed material but is related to the flow depth (i.e., mean dune length and mean height increase with mean flow depth). This relationship between dune size and flow depth suggests that the bedforms result from some interaction between large eddies in the flow and the sediment bed.

DUNES

SEDIMENTOLOGY

The hydraulic conditions that generate **ripples and dunes** take place at ***Froude numbers < 1.*** Under these flow conditions, either the water surface shows little disturbance or the water waves are out of phase with bedforms, and flow is said to be in the ***lower flow regime***

With further increase in flow velocity, dunes are destroyed and give way to an ***upper flow regime*** stage of flow, which takes place at *Froude numbers >1.* Rapid flow of water takes place, which generates surface water waves that are in phase with bedforms.

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Antidunes are low, undulating bedforms up to 5 m in length which form in very fast, shallow flows. They migrate upstream during flow, giving rise to low-angle (< 1 0 °) cross-bedding directed upstream.

SEDIMENTOLOGY

WAVE GENERATED BEDFORMS

A back and forth motion of sediments results in a formation of oscillation ripples corresponding in scale to the wave oscillation.

- Ripples that form by wave action under oscillatory flow are called **oscillation ripples**. Oscillation ripples tend to be nearly symmetrical in shape and have fairly straight crests.
- **Oscillation ripples** are very common structures formed in areas of lakes and seas that are shallow enough for wave action to move sediments on the bottom