Lecture 11

Processes of transport and sedimentary structures

Sediment transport and deposition

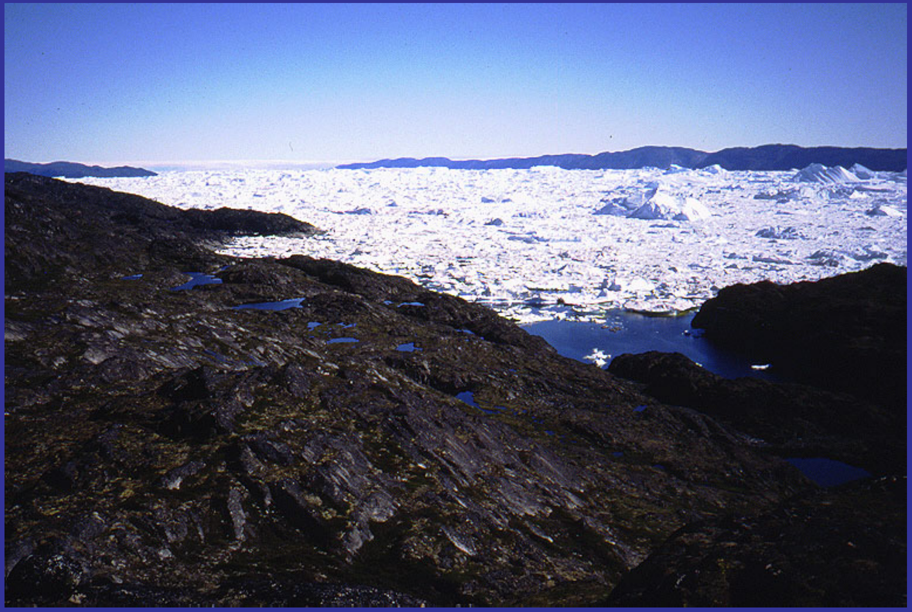
- **Transport media**

Sediments are transported from source areas to depositional areas by:

- Water
  - Overland flow, channel flow.
  - Waves, tides, ocean currents.
- Air
  - Can pick up dust and sand and carry it large distances.
  - The low density of air limit the capacity of wind to transport material.
- Ice
  - High-viscosity fluid which is capable of transporting large amount of clastic debris.
- Gravity
  - Rock falls (no transport medium involved).
  - Debris flows, turbidity currents (water involved).

<u>Each transport media operates in different ways, and will result in different sediment forms.</u>





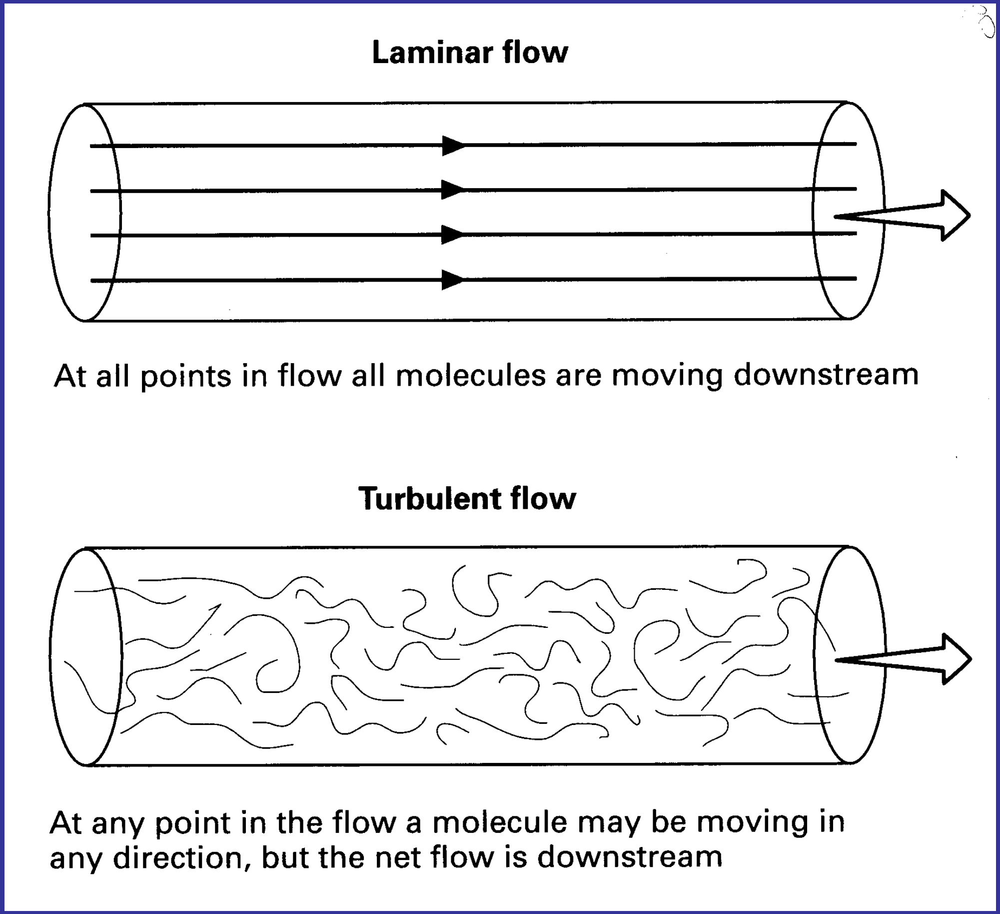

Laminar and Turbulent Flow

A fluid in motion can move in two distinct ways:

➢In laminar flows all molecules within the fluid move parallel to each other in the direction of transport.

➢ In turbulent flows, molecules in the fluid move in all directions but with a net movement in the transport direction.

• Most Geologically significant flow processes are ***Turbulent.***



Reynolds number (laminar vs. turbulent flow)

$$\mathrm{Re} = \frac{ul}{\upsilon}$$

u=flow velocity; l=characteristic length (flow depth); υ=kinematic viscosity (dynamic viscosity/fluid density)

- Turbulence is promoted by high flow velocities and flow depths, and low viscosities (Re>2000); laminar flow occurs when the reverse is the case (Re<500)

✓Air has a very low viscosity and thus will be turbulent even at low velocity (air is always turbulent at velocities capable of sediment transport).

✓ Increasing velocity will transform laminar flow into turbulent flow.

✓ Water will only show laminar flow at low velocity or shallow water depth.

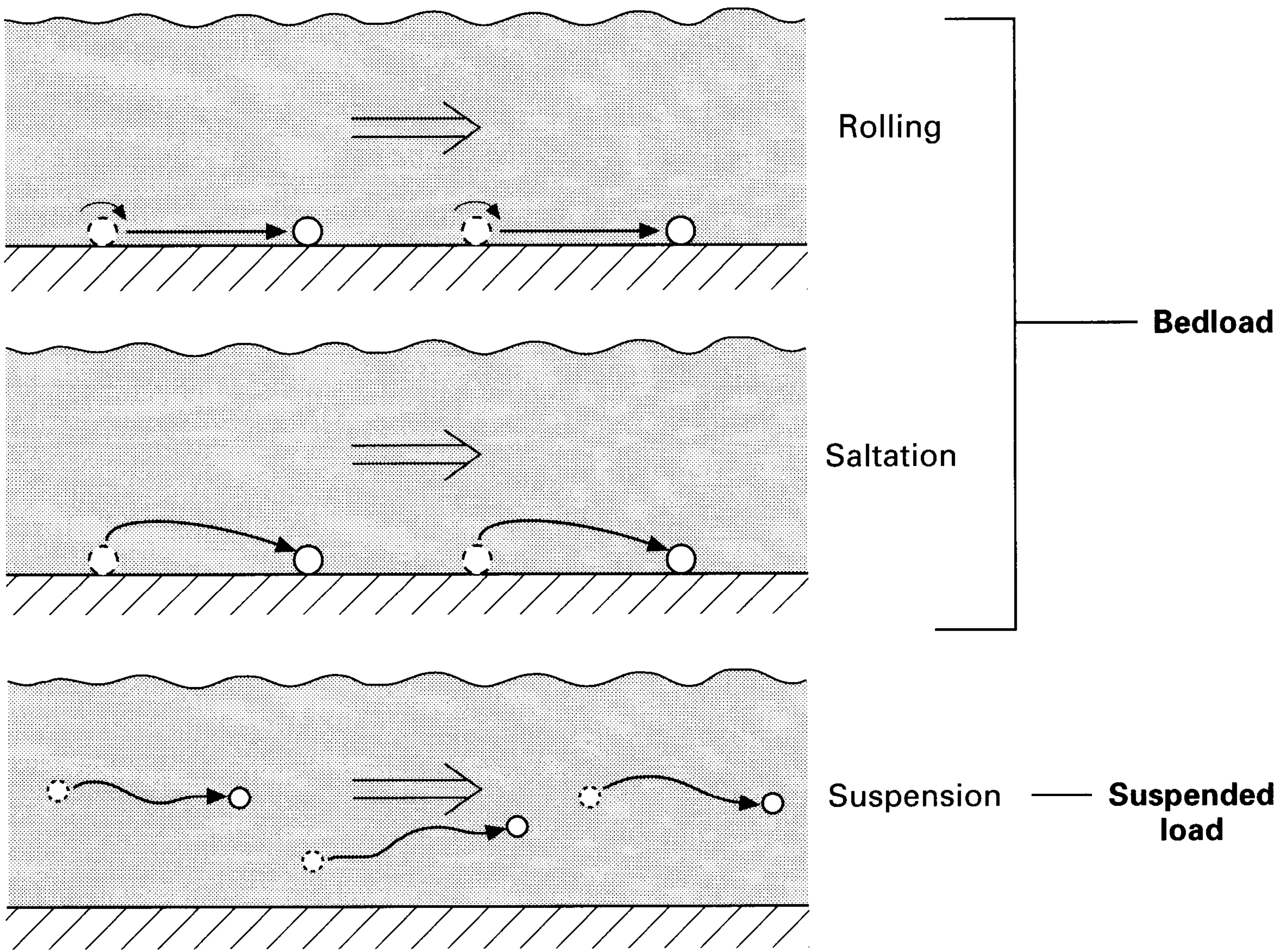
✓ Most flows that are capable of transporting large quantities of sediment are turbulent.

Transport modes in a turbulent fluid

- **Traction** (rolling over the bed surface)
- **Saltation** (jumping over the bed surface)
- **Suspension** (permanent transport within the fluid)
- **Solution** (chemical transport)

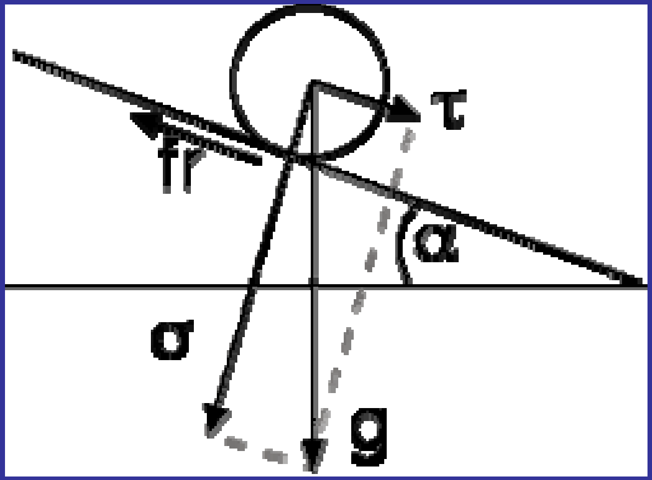
- ✓ Factors that control the motion is: flow velocity, turbulence, sediment mass and particle surface relative to their mass.

- ✓ Particulate matter carried by a flow is normally considered in terms of ***bedload*** (rolling and saltating particles) and suspended load (material in suspension), also sometimes referred to as ***washload***.


Rolling
Saltation
Bedload
Suspension
Suspended load

Four key physical aspects of sedimentation: gravity, shear stress, normal stress, friction

- *gravity (g)* is a force that acts to attract two masses. In this case it is acting between a grain and the Earth. It pulls the grain straight down into the earth.
- *shear stress (τ)* is force acting per unit surface area parallel the surface. It is that component of gravity acting along the surface.
- *normal stress (σ)* is force acting per unit area at right angles to the surface. It is that component of gravity acting into the surface.
- *friction (fr)* acts parallel, but opposite, to τ. Coefficient of friction is a constant for given surface material.

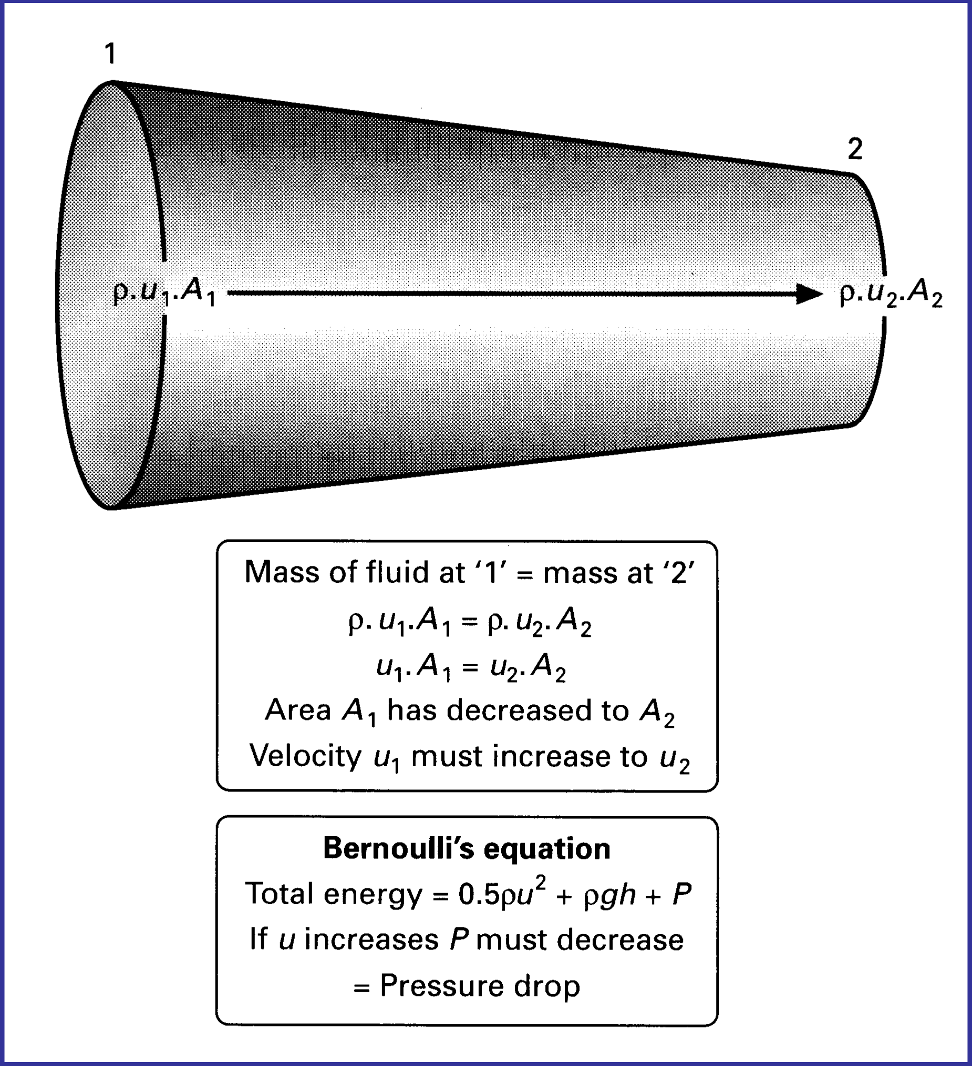


Sediment transport and deposition

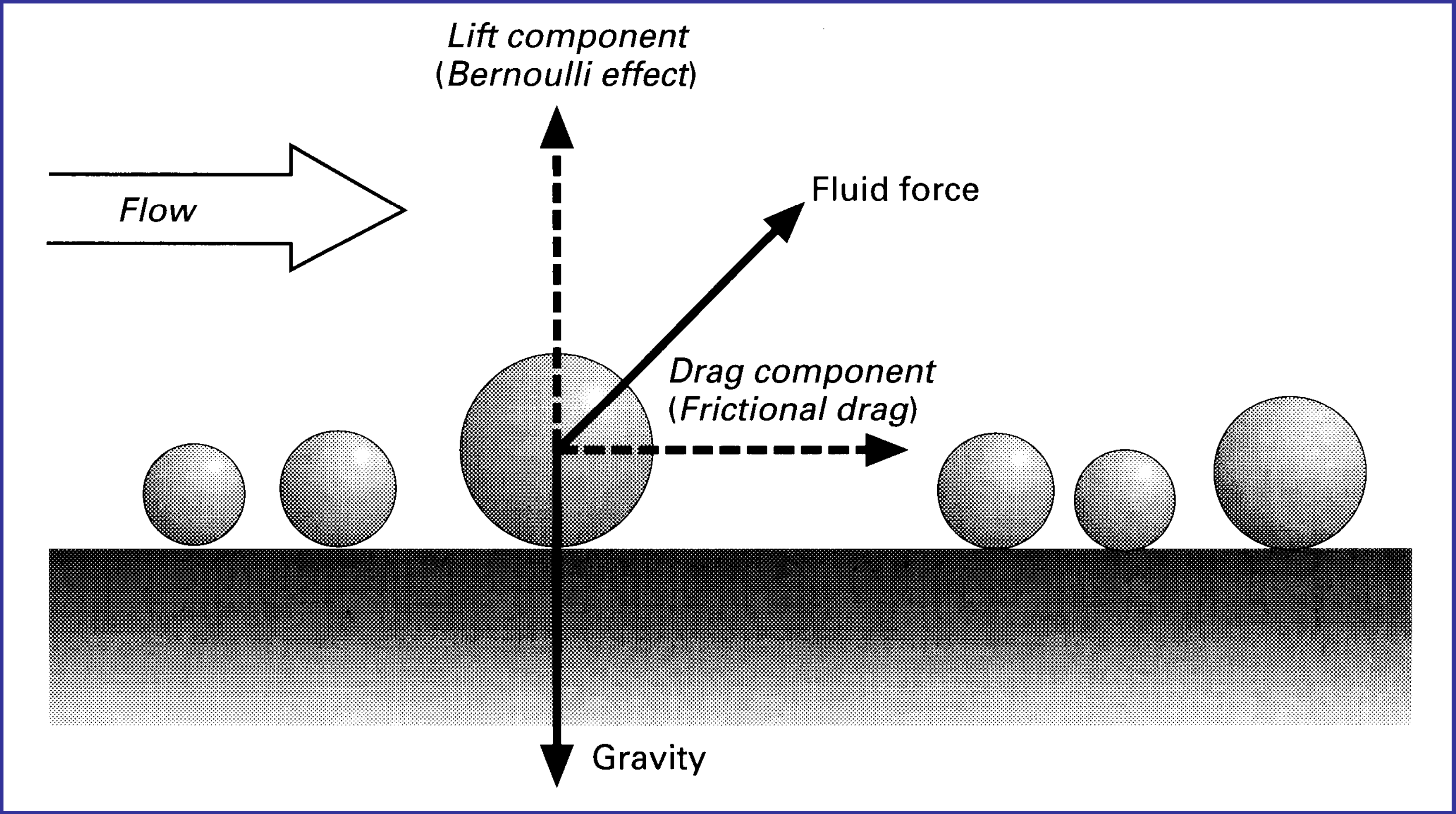
- The **Bernouilli effect** is the reduction of pressure, proportional to the increase of flow velocity as the flow encounters an obstacle (sediment particle), leading to a lift force and entrainment of the particle

- Drag forces and lift forces act together to cause entrainment of sediment grains

- The **boundary layer** is that part of the flow influenced by frictional effects



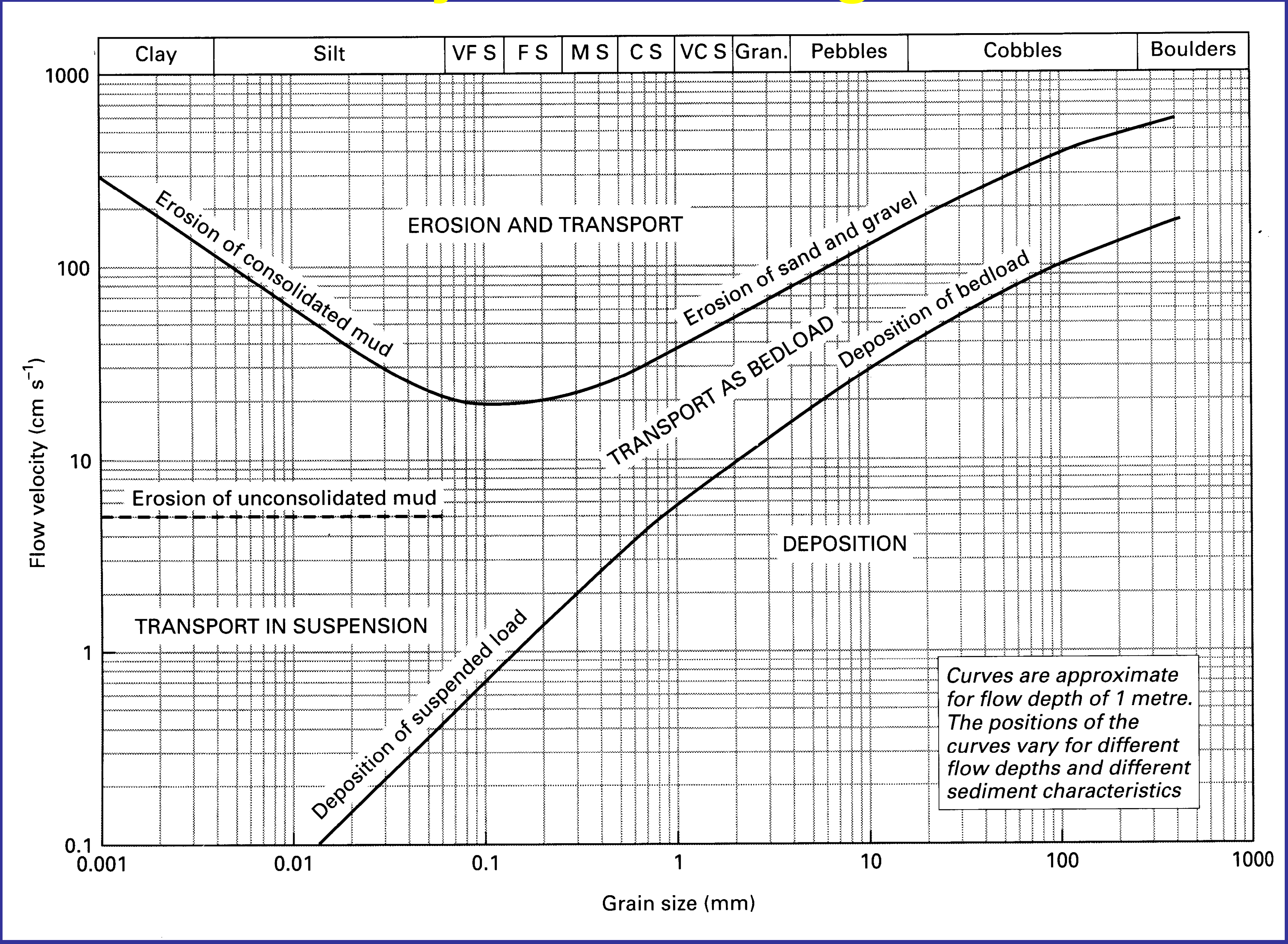
Forces acting on a grain in a flow



Grain size and flow velocity

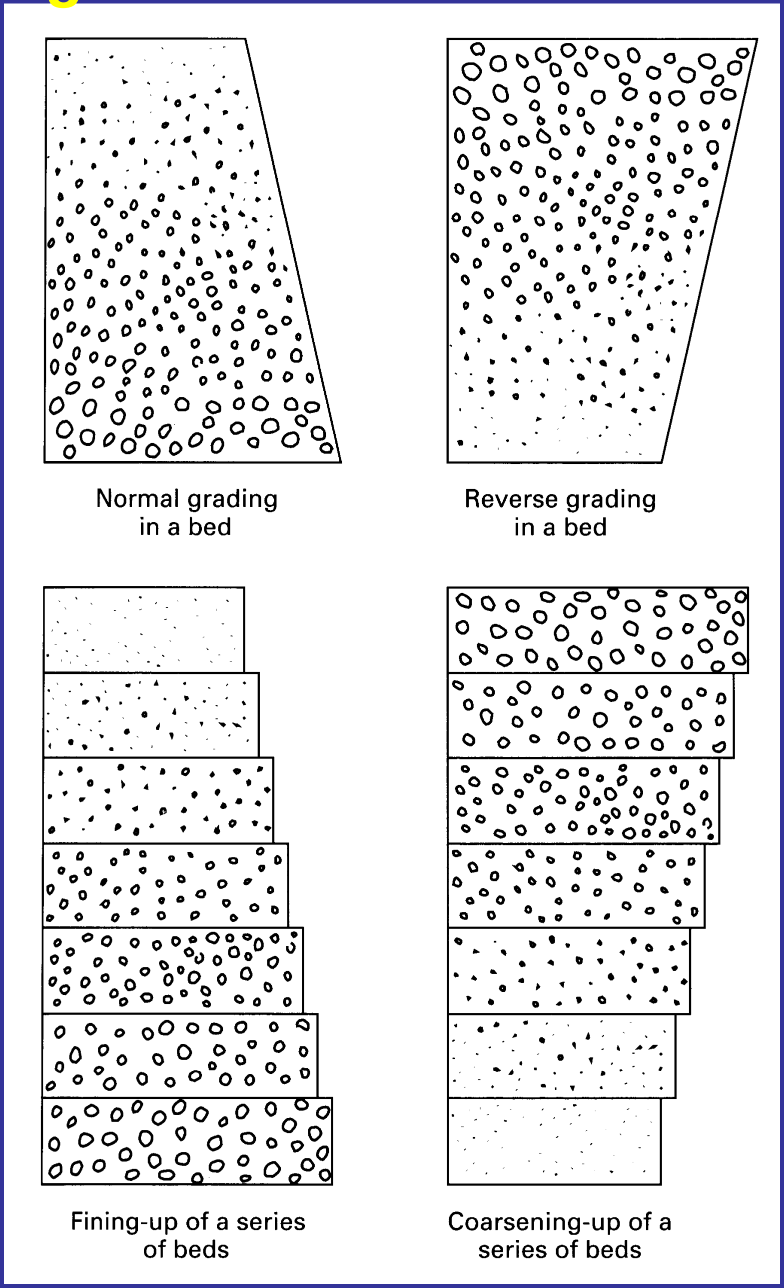
- **Hjulstrom diagram**: shows the relationship between water flow velocity and grain size.
- The water speed that is required to transport a grain is called the “critical velocity”.
- The smaller silt and clay particles require higher velocity to move them than sand. This is because small particles such as silt and clay can be **cohesive**.
- In environments where water energy (flow) varies through time (for example, tidal environments), cohesion explains how layers of clay may come to be interbedded with layers of sand.
- The smaller the grains, the bigger the effect of surface charge, thus the stronger the flow needed.

Hjulstrom diagram

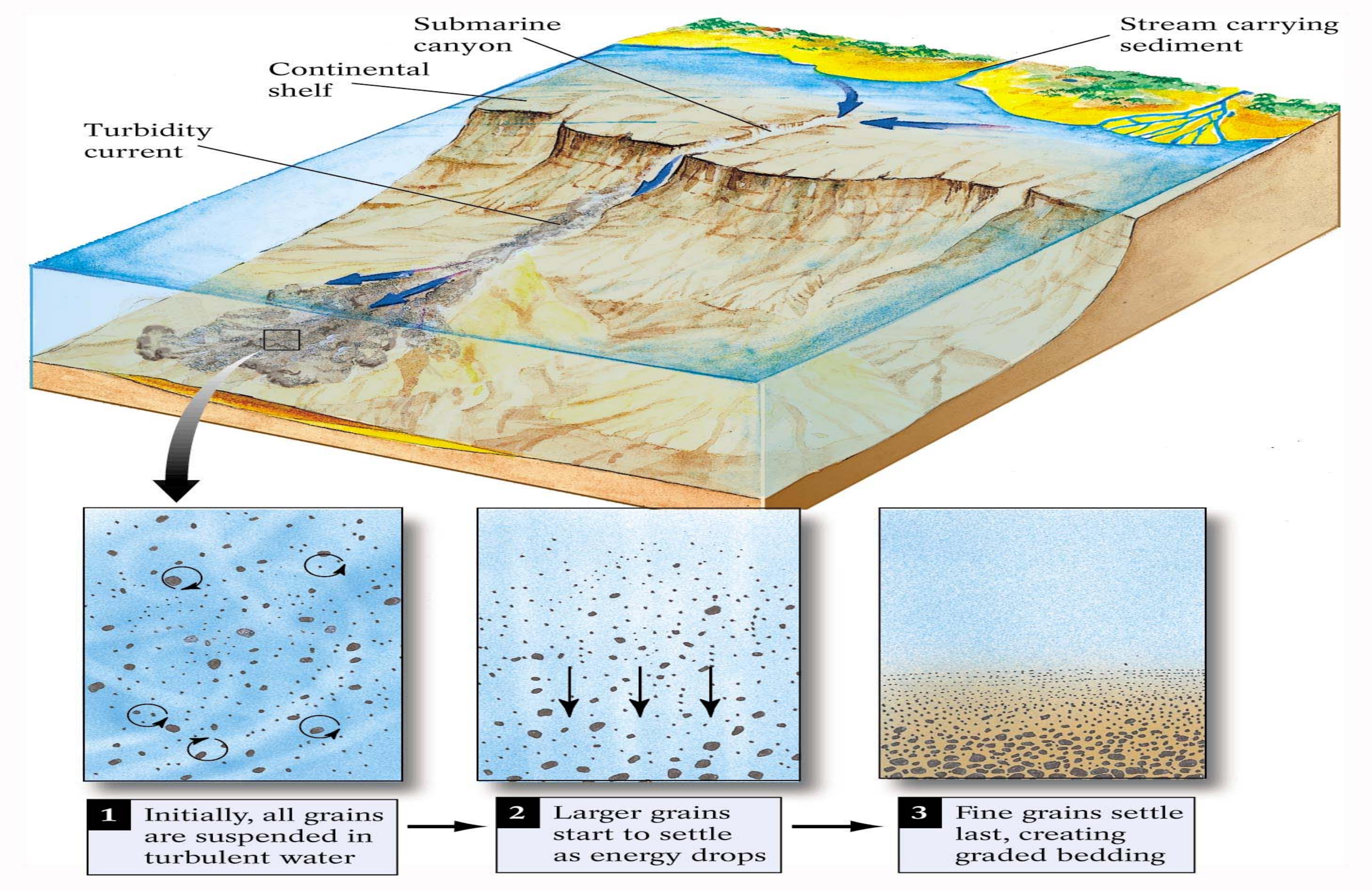


Clast size variations: graded bedding

- **Laminae** and **beds** are the basic sedimentary units that produce stratification; the transition between the two is arbitrarily set at 10 mm.
- **Normal grading** is an upward decreasing grain size within a single lamina or bed (associated with a decrease in flow velocity), as opposed to **reverse grading.**
- **Fining-upward successions** and **coarsening-upward successions** are the products of vertically stacked individual beds.
- Normal grading is an important characteristic of many turbidity current, overbank flooding and delta top settings.



Graded bedding of sediment

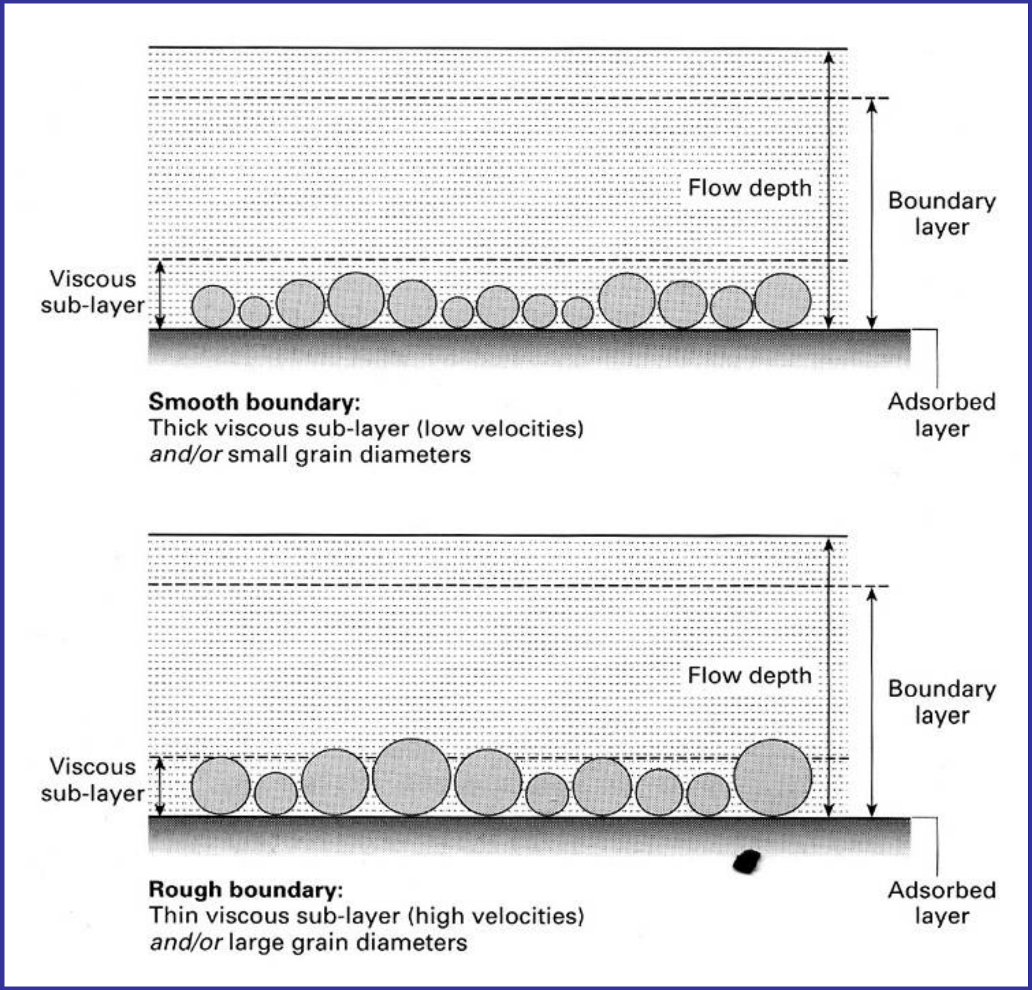


Sediment transport and deposition

- Critical velocities are different for sediment entrainment and deposition, especially in the finer fractions
- Fluid density and viscosity play a key role in determining which particle sizes can be transported
- The amount of sediment transport is not only related to flow velocity (or bed shear stress) and grain size, but also to:
  - Grain density
  - Grain shape

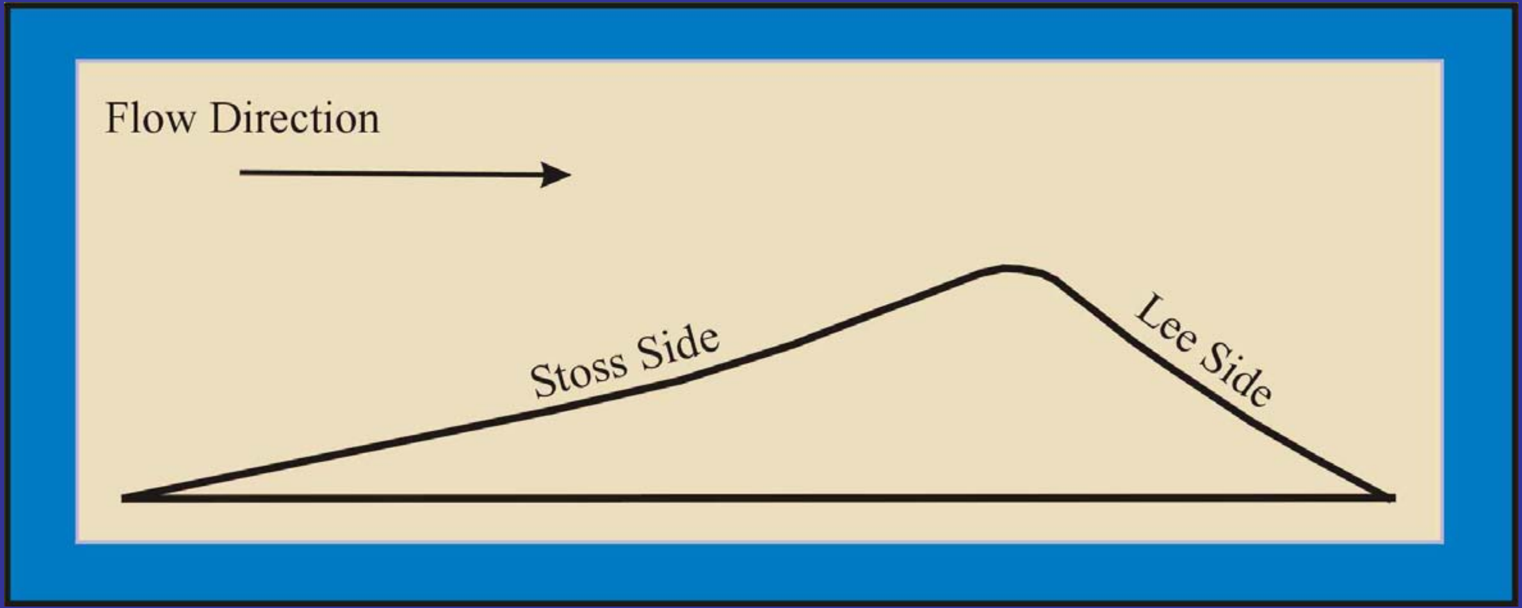
Flows, sediment and bedforms

- A bedform is a morphological feature formed by the interaction between a flow and sediment on a bed.
- There is friction forces within a flow and is greatest at the edges of the flow. A number of layers can be found in the fluid.

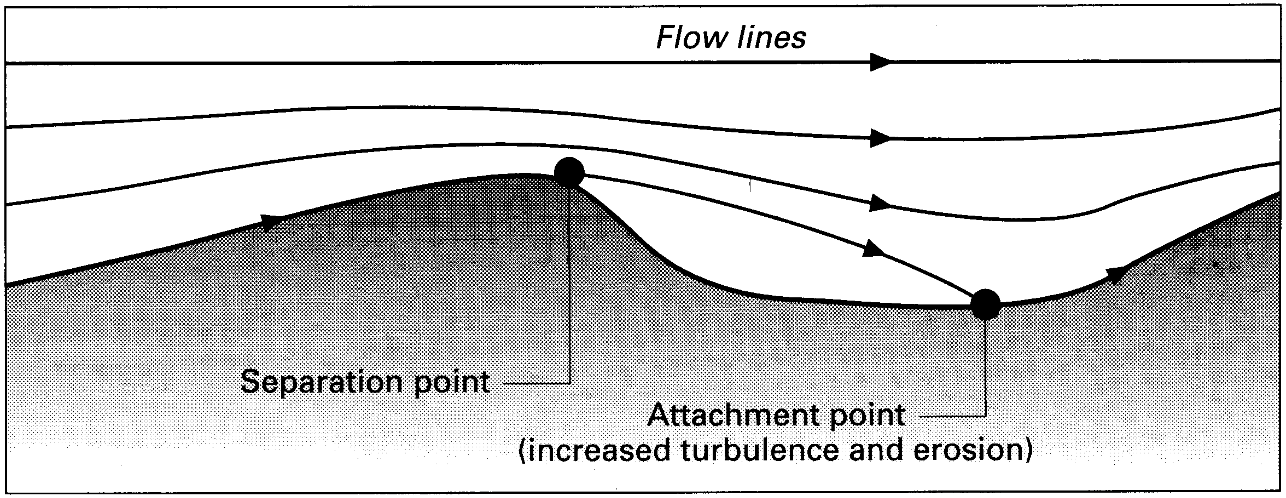


Current ripples

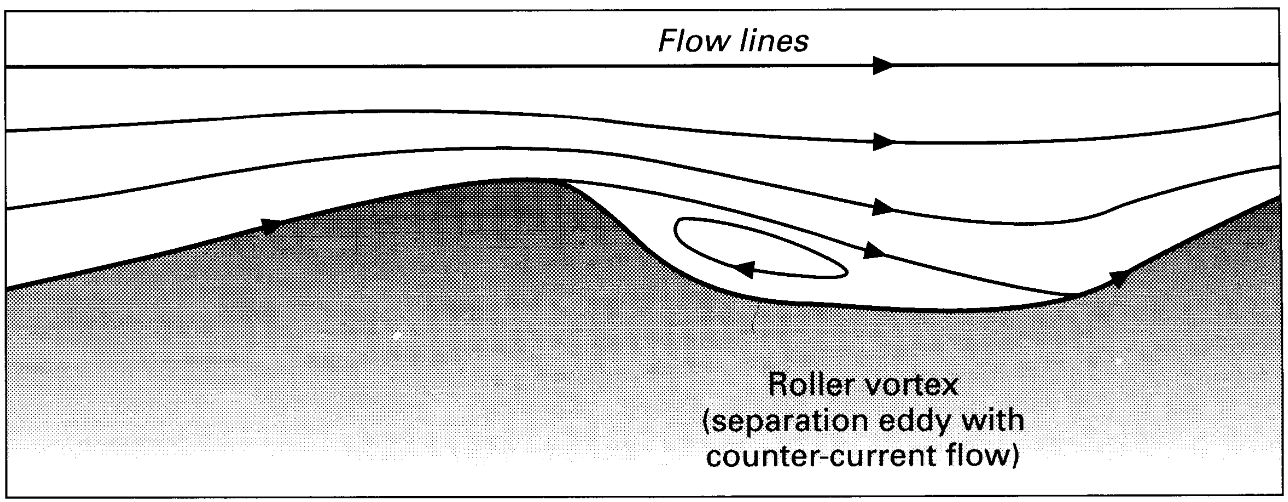
- Current ripples are small bedform formed by the effects of boundary layer separation on a bed of sand.
- Current ripples have a stoss side (erosion and transport) and lee side (deposition), the latter with a slope of ~30° (angle of repose).
- Current ripples only form under moderate flow velocities, with a grain size <0.7 mm over a smooth bed.



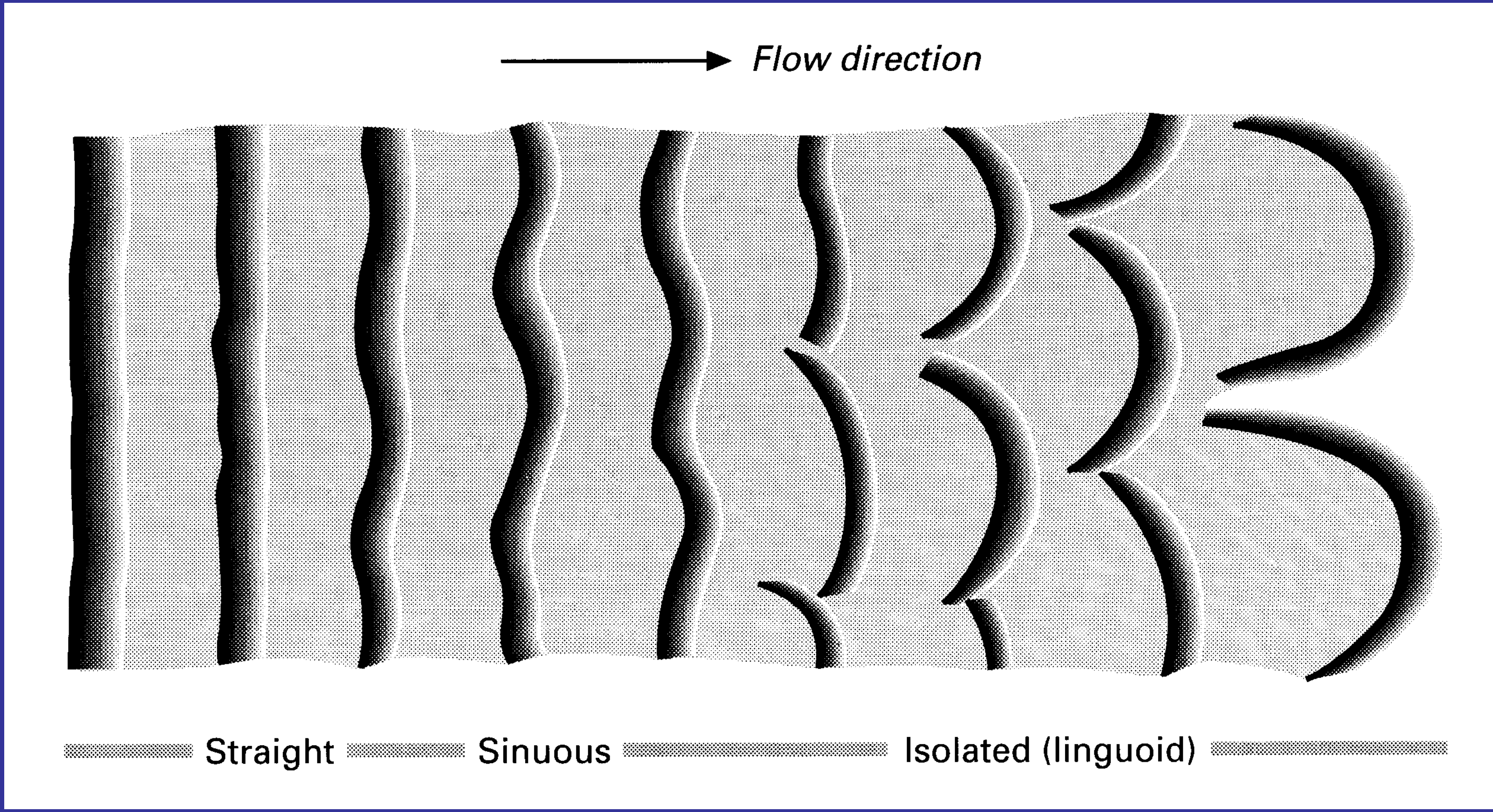
1. Erosion in the trough of a bedform



2. Development of counter-currents in lee of bedform



Plan view of current ripples

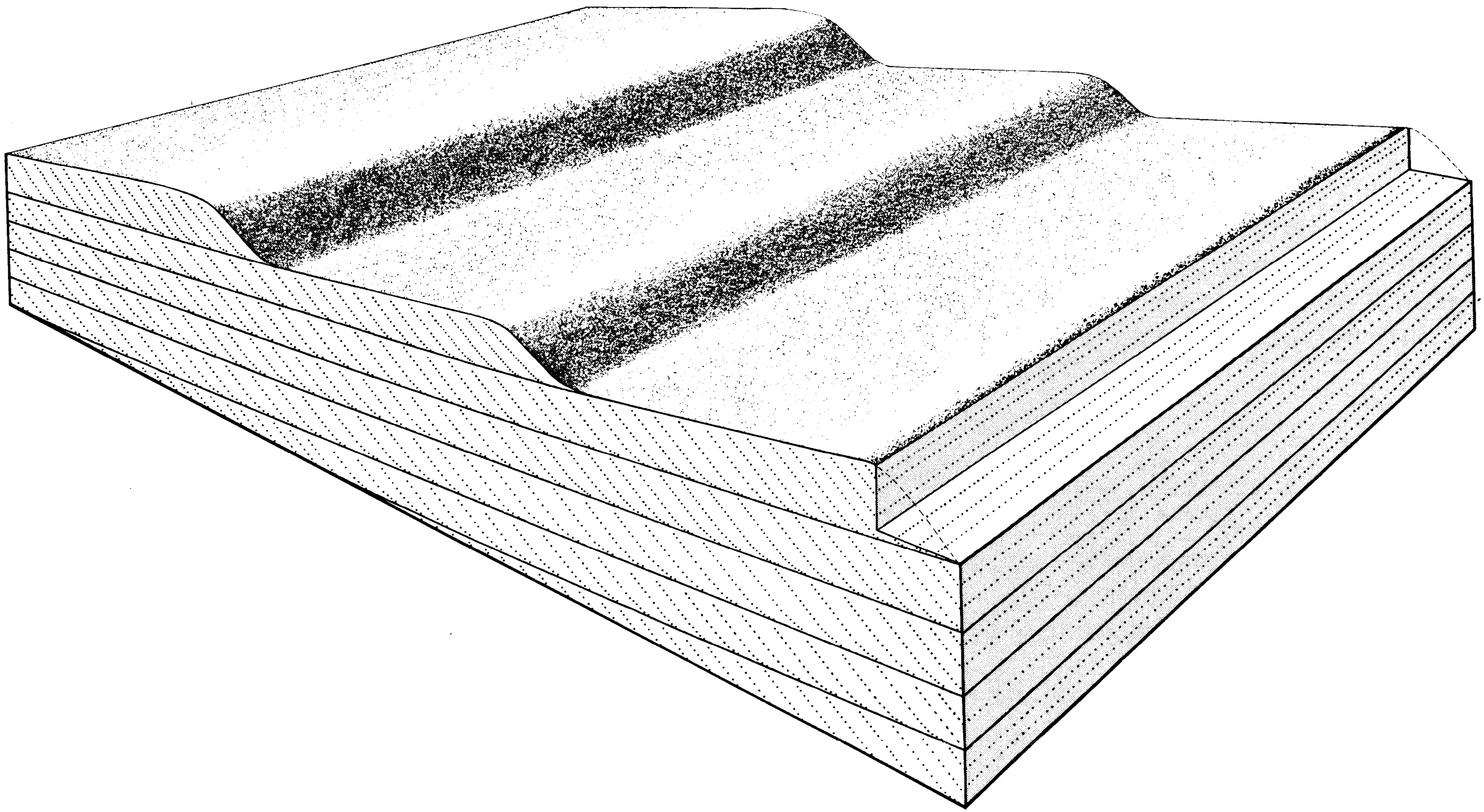


Current Ripples

Current Ripples (Water)

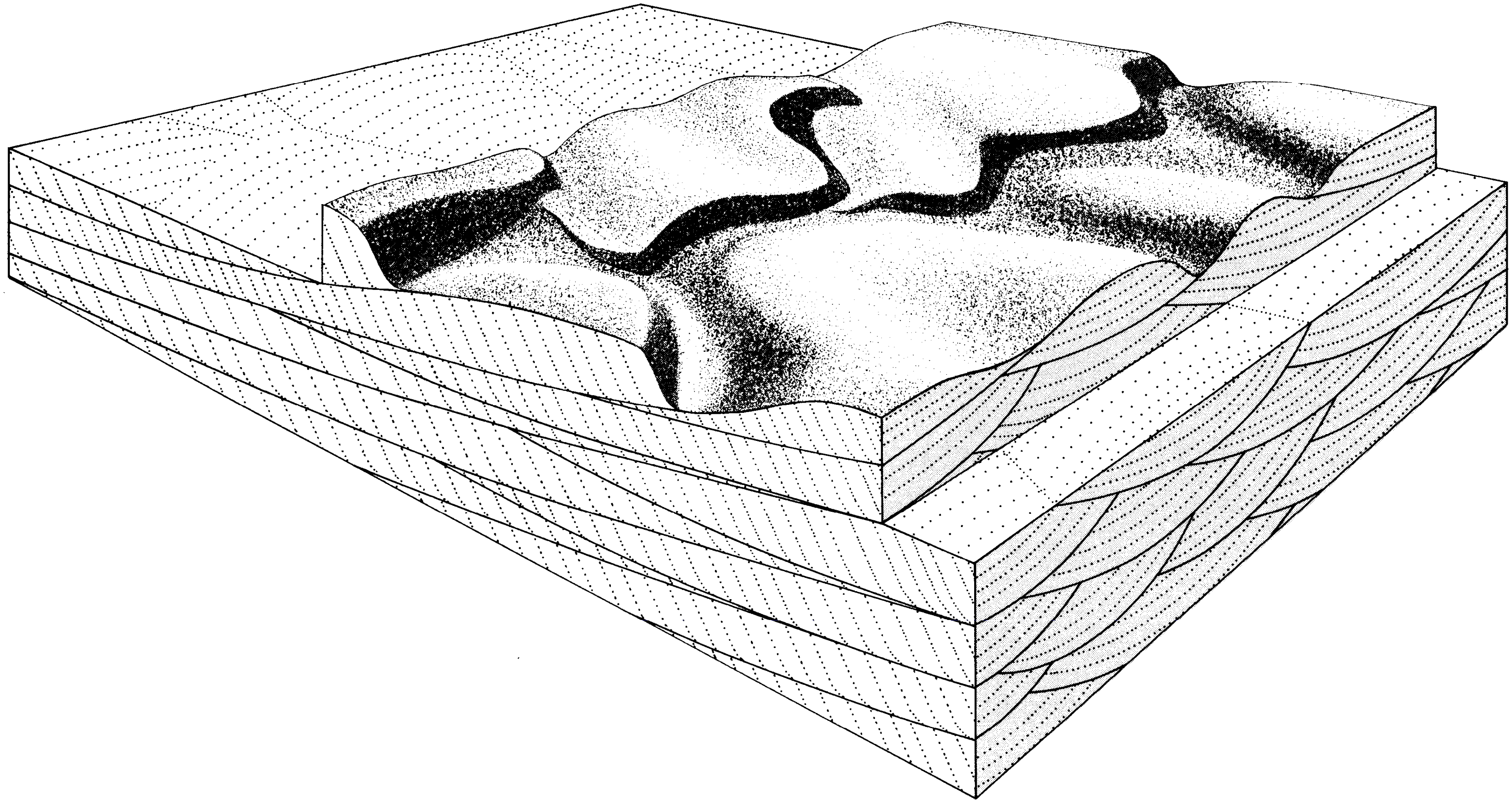
Wind Ripples

Straight crested bedforms

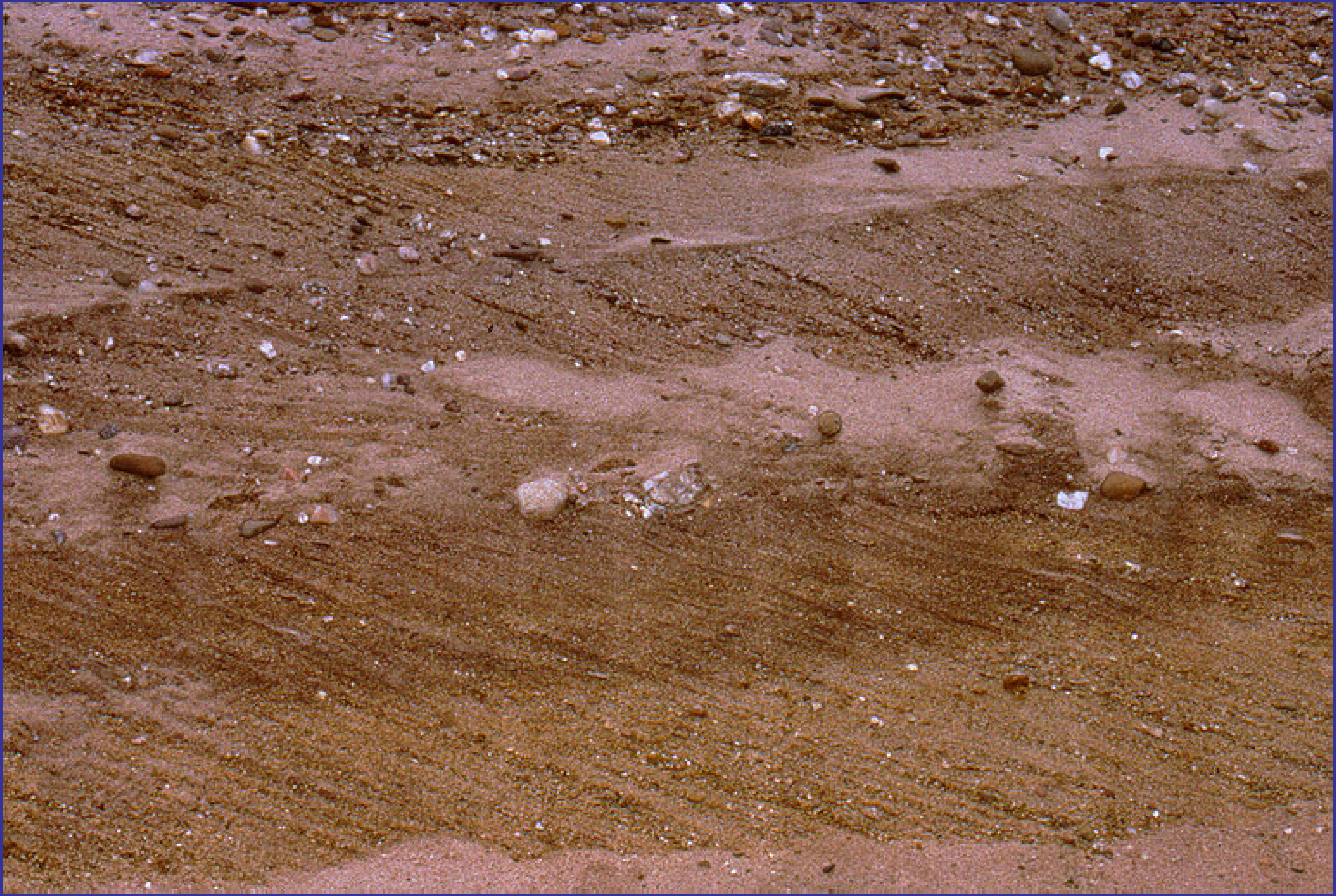


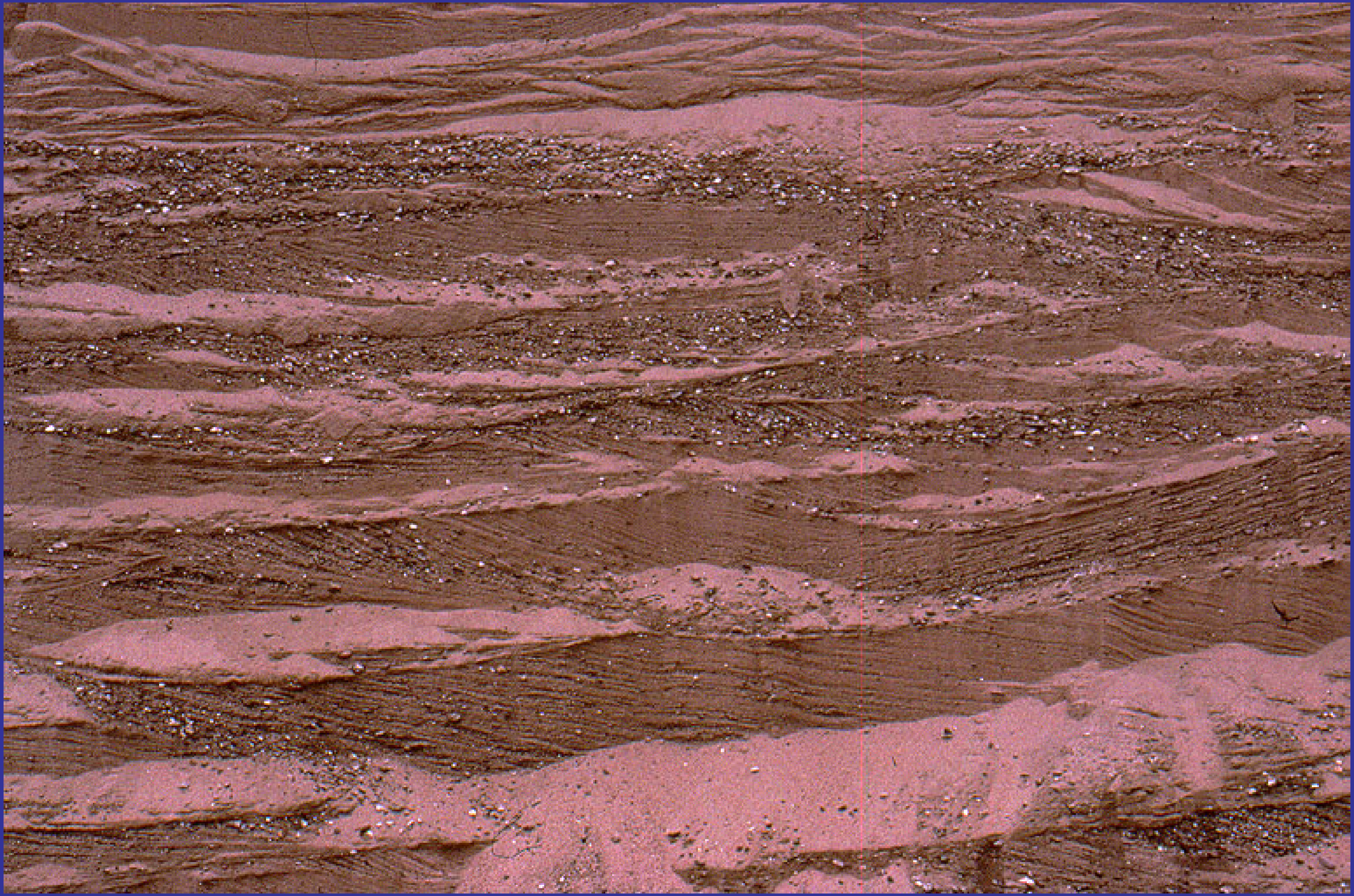
Planar cross lamination

Sinuous crested bedforms



Trough cross lamination





Climbing ripple cross lamination

Produced when the addition of sediment from the current exceeds the forward movement of the ripple, deposition will occur in the stoss side as well as in the lee side.