Transport and depositional processes

Sediment gravity flows

Goals for today's lecture

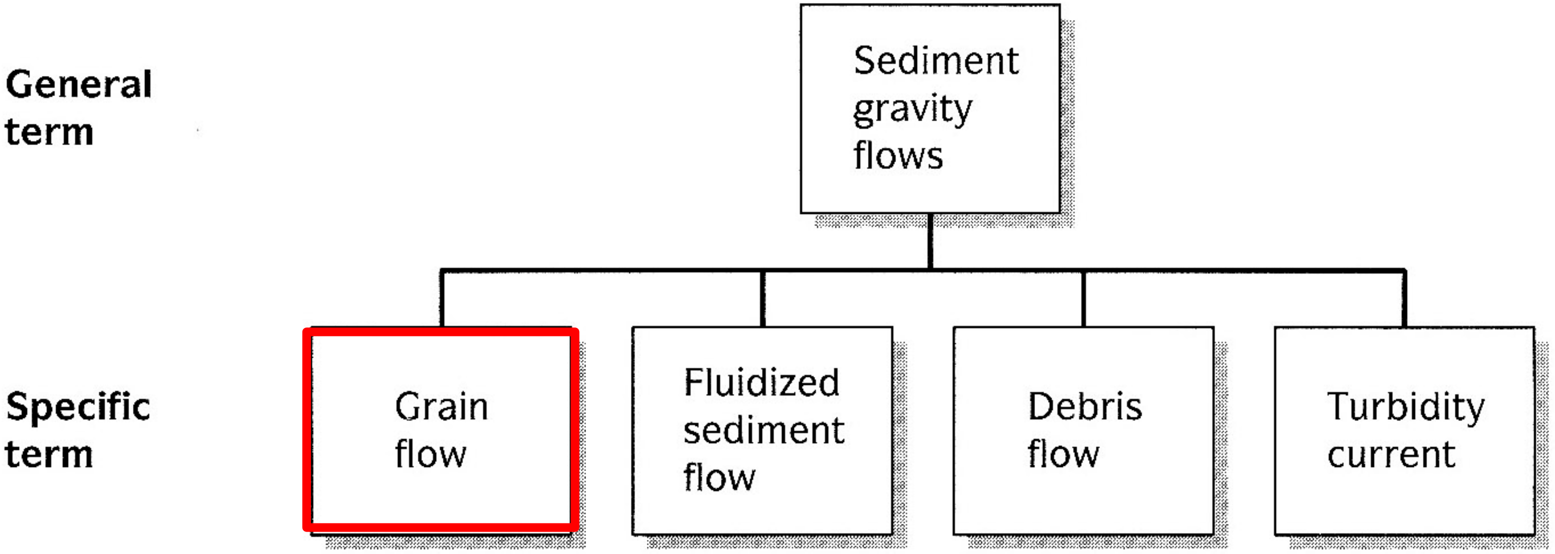
- Define what a sediment gravity flow is.
- Know what the four types of gravity flows are.
- Identify some of the ***key processes/concepts*** associated with the flow types.
- Connect the gravity flows to their respective deposits.

Transport of clastic sediments:

- Weather rock is eroded, the product of erosion is transported, and then deposited.
  - Dry mass wasting driven by gravity.
    - Rock falls, landslides
  - Fluid transport, driven by flowing fluid
    - Streams or windstorms
  - Sediment Gravity Flows
    - Grain flow, fluidized sediment flow, debris flow, turbidity current

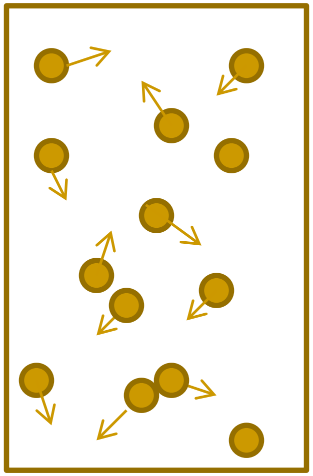
Sediment gravity flows

- *Fluid assisted movement of sediments that is gravity driven*.
  - Caused by a breakdown in grain packing.
  - Occur when internal friction and cohesiveness low.
  - Results in a internal deformation of the sediment mass.



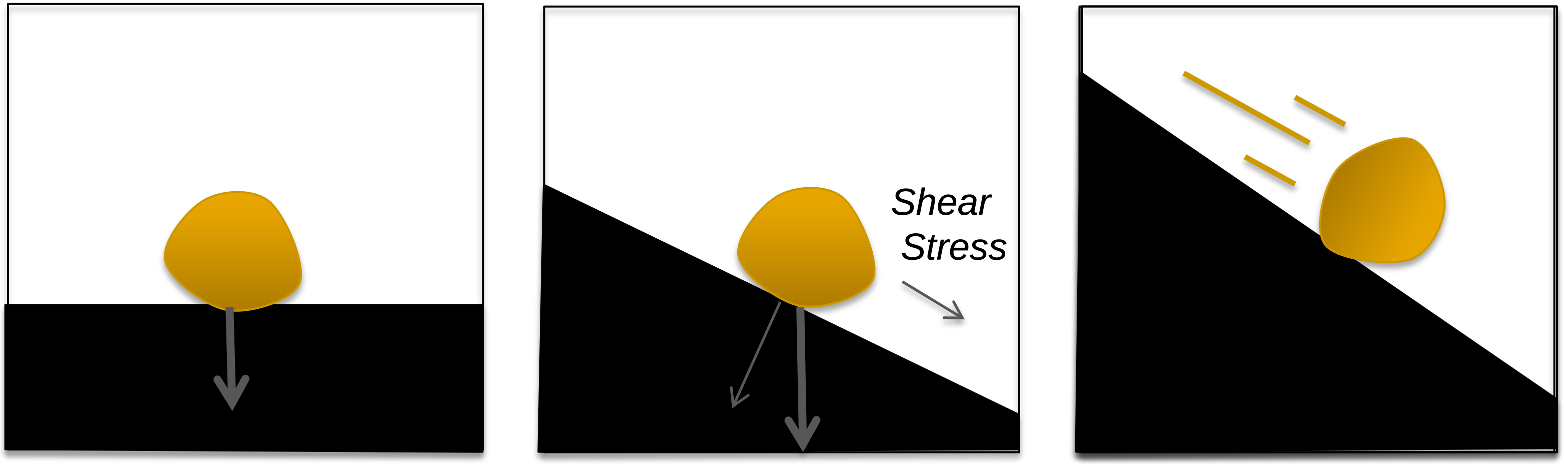
1) Grain flows

Grain flow



- Cohesionless sediment moves, as driven by gravity.
- Air trapped between grains acts as a lubricant, but does not propel the grains
- Energy to continue flow is supplied by internal grain collisions.
    - Occur on slopes that exceeds the ***angle of repose***.

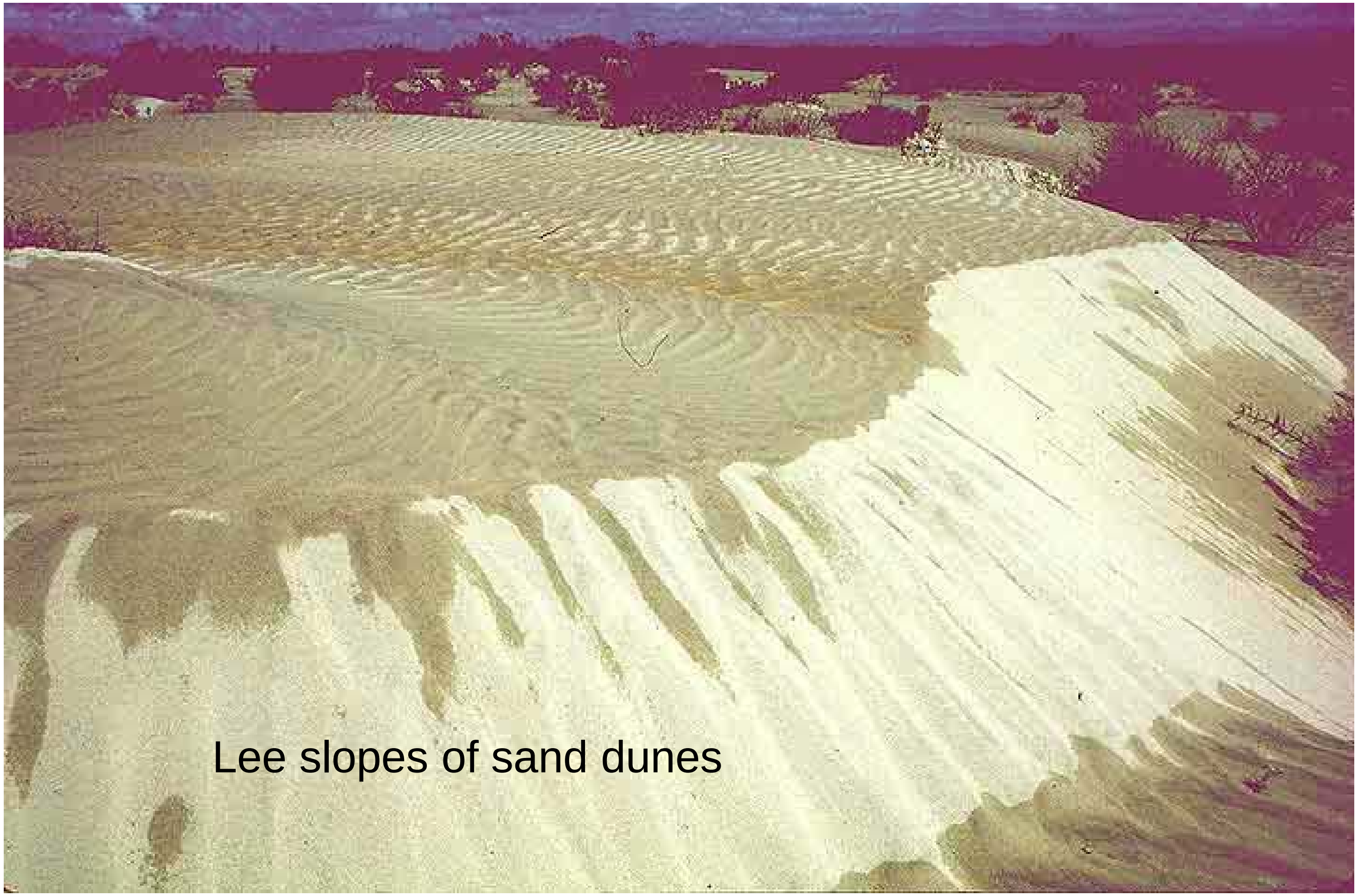
Angle of repose



- Forces acting on a grain of sediment can be divided into two components:
  - Shear Stress pulling the grain down the slope.
  - Shear Strength of the material holding the grain in place (friction, cohesion to other grains.
- The angle of repose is the steepest slope where **Shear Strength > Shear Stress**

So, what factors can affect the angle of repose in sediments?

Example of grain flows



Grain flows

- Cohesionless sediment (reduced shear strength)
  - Air
    - Supported by <u>dispersive pressures</u> (direct grain-to-grain collision)
  - Water
    - Collisions and close approaches
  - Can flow rapidly down slopes owing to <u>loss of shear strength</u>
    - Steep slopes (increased shear stress) that exceeds the **angle of repose**
      - **Increases with grain size, but usually lies between about 30 and 37^{o}**
      - May grade into liquefied flows

Grain flow deposits

- Single grain flow are usually just a few cm thick for sand-sized grains.
- Deposition occurs when kinetic energy of the particles falls below threshold.
- <u>Reverse graded beds</u>
  - Smaller particles filtering down through the larger particles during dispersed state
    - **Kinetic sieving**

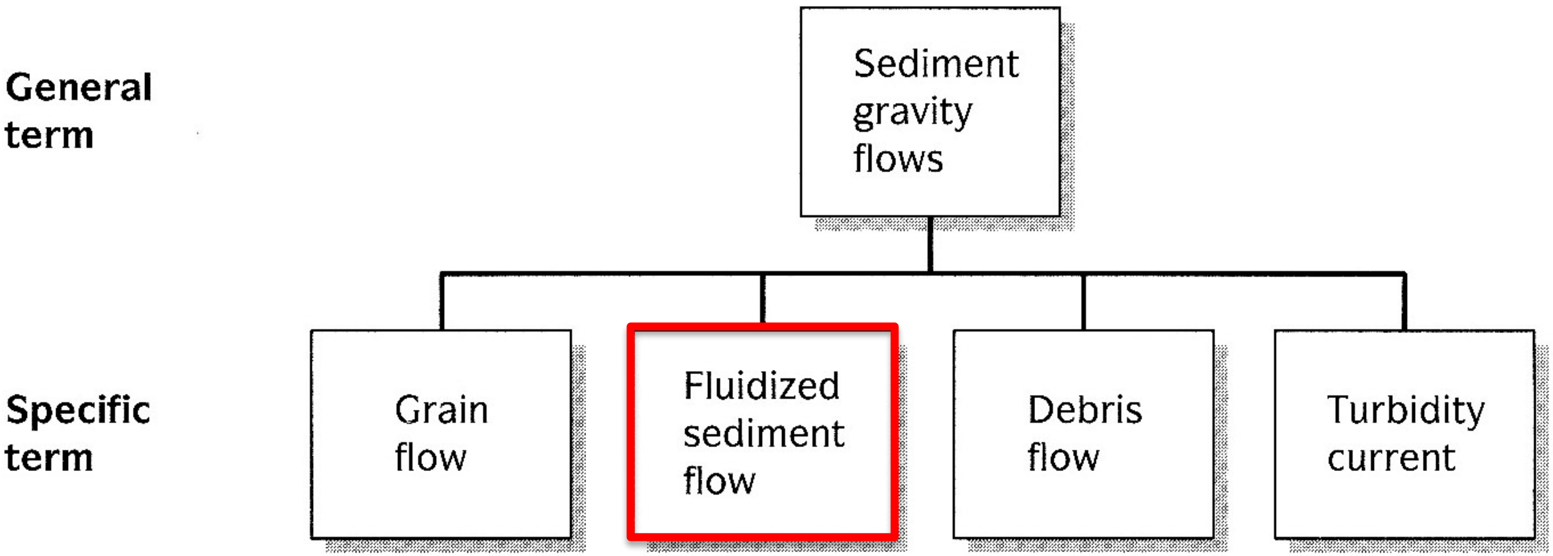
Fine grained material

Example of grain-flow deposits

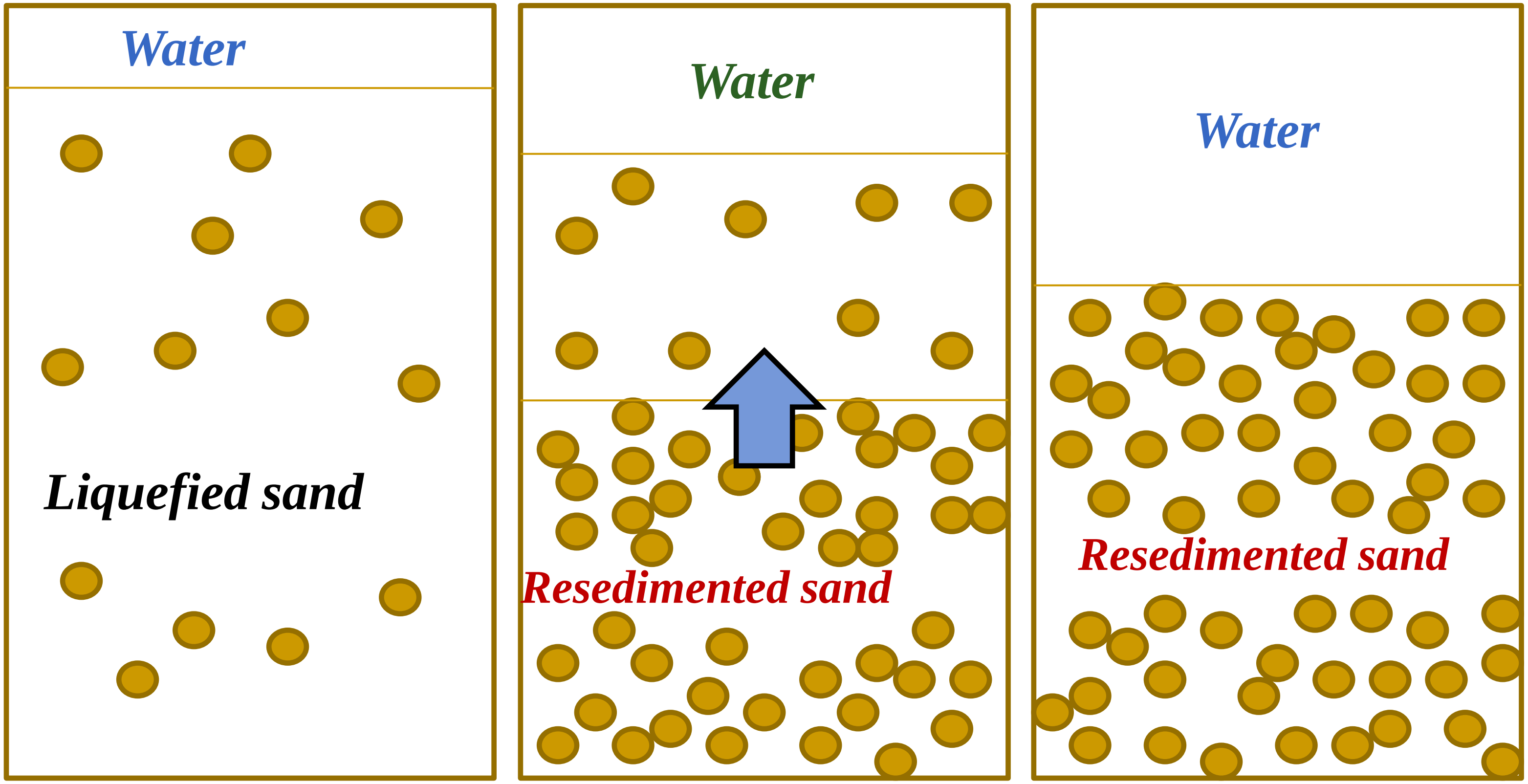
Navajo Sandstone

Seds.utah.edu

SEDIMENT GRAVITY FLOWS



Liquefaction



So what’s wrong with this example of a liquefied sediment?

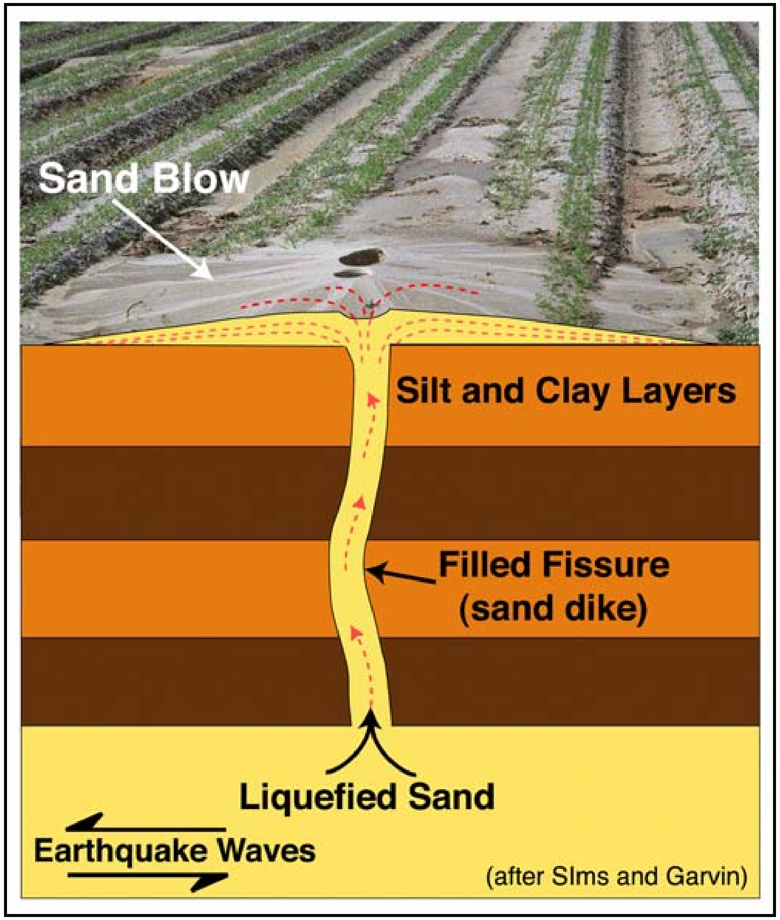
Video: 20th Century Fox

Sand Volcanoes shortly following an Earthquake

Soil liquefaction

Fluidized sediment flow deposits

- Thick deposits (10s of cm+)
- “Poorly sorted” sand units
- Characterized by fluid escape structures.
  - Internal dish structures
  - Pipes of liquefied sediment leading to Sand “volcanoes”

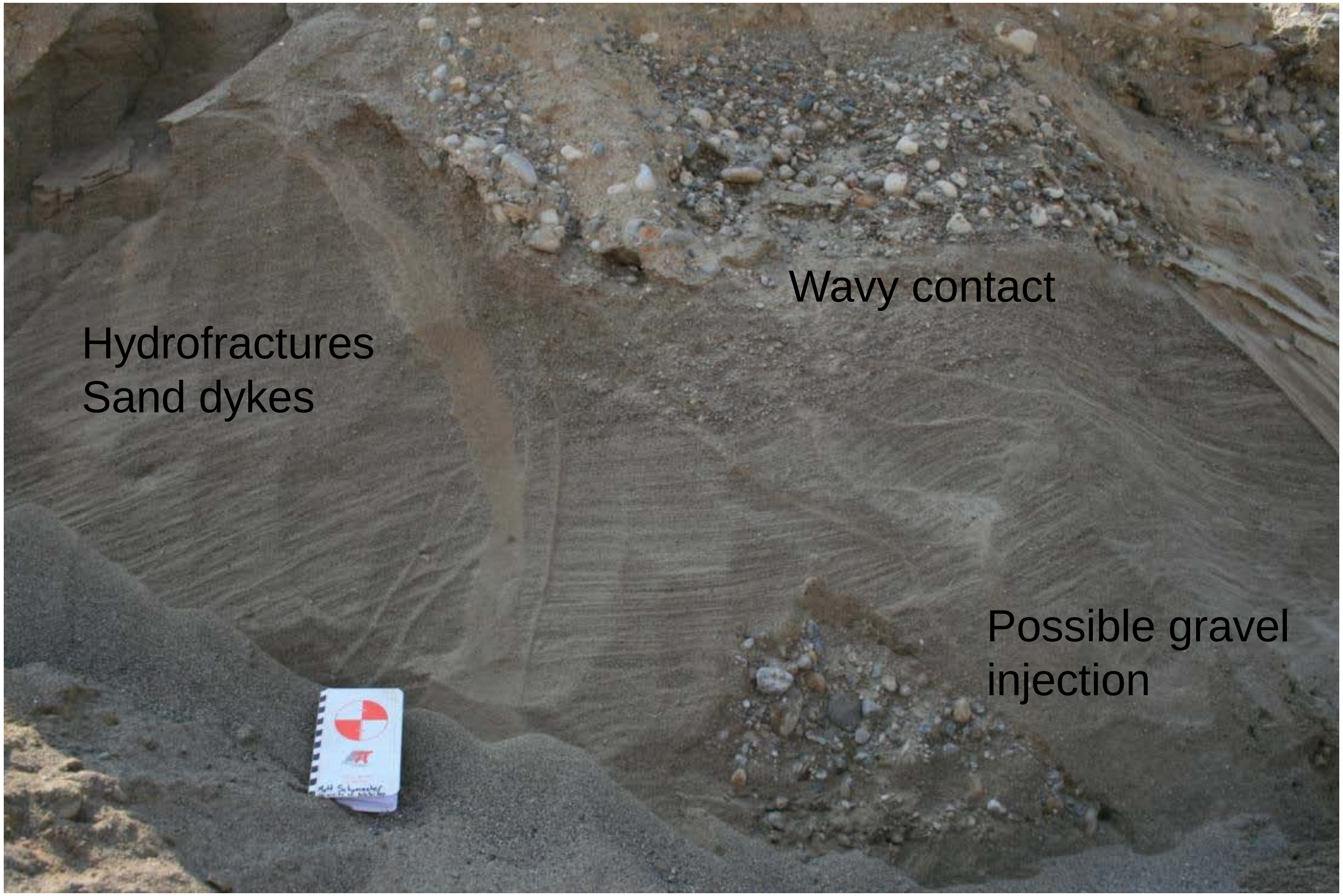


http://mptuttle.com/newmadrid3.html

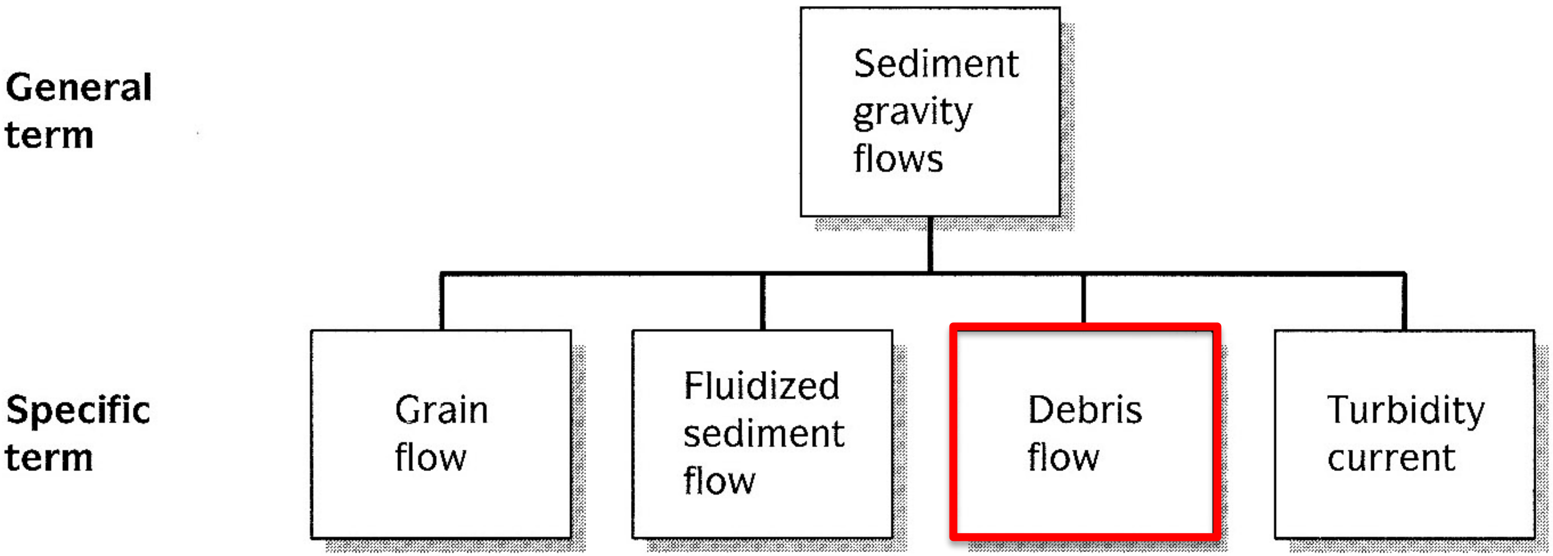
“Dish and Pillar” structures

Lowe, D.R., 2006

Some sedimentological characteristics



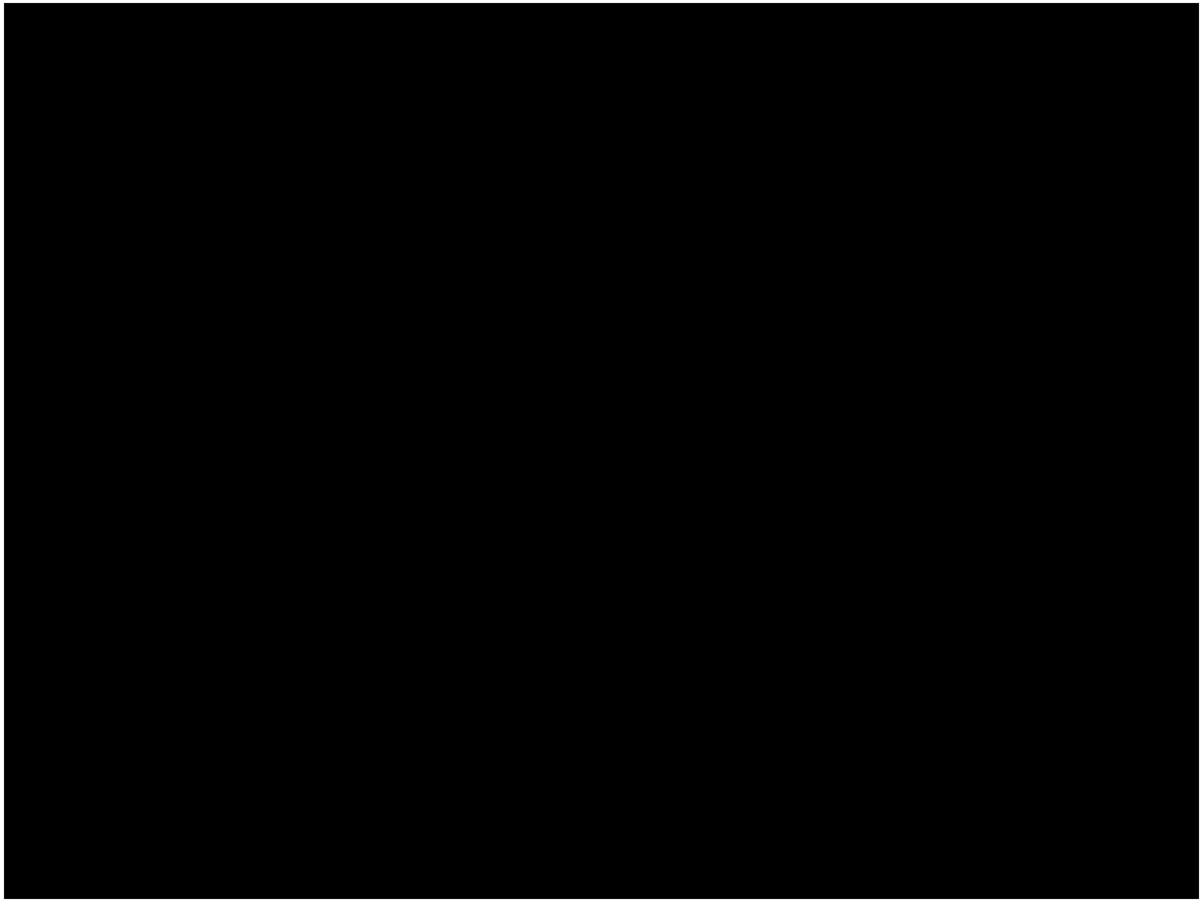
SEDIMENT GRAVITY FLOWS



3) Debris flows and mud flows

- Slurry-like flows composed of a mass of liquefied mud that move downhill under the force of gravity.
  - Contain a wide range of grain sizes.
  - Clasts are supported by strength and buoyancy of the matrix.
- Triggered by the near saturation of loose sediment on steep slopes.
- Flows are common in arid and semiarid regions.
  - Vulnerable to rapid saturation.
  - Also near volcanoes with saturation of loose pyroclastic material.

Debris flow



Video: SERC Carleton College

Impact of debris flows

Photo: L. Smith

Venezuela, 1999

Debris flow deposits

- Deposition via mass emplacement.
- Multiple grain sizes.
- Complex orientation of clasts.
- Can be reverse graded beds.

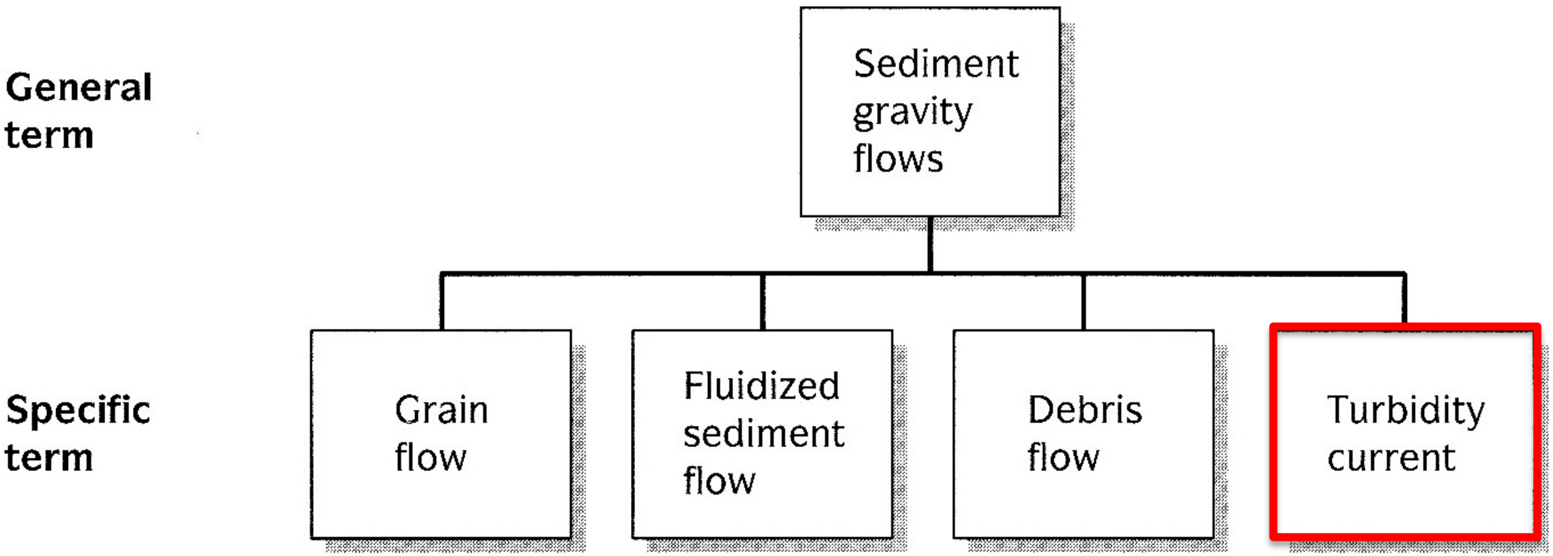
Photos: M. Ross

More distal facies...

Peru 2012 – Lima (Miraflores)

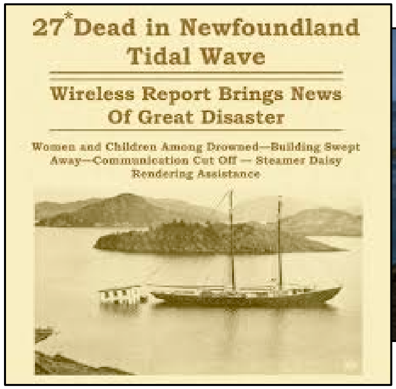
Debris flow deposits

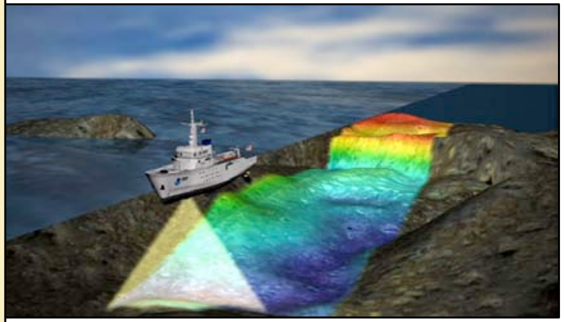
SEDIMENT GRAVITY FLOWS

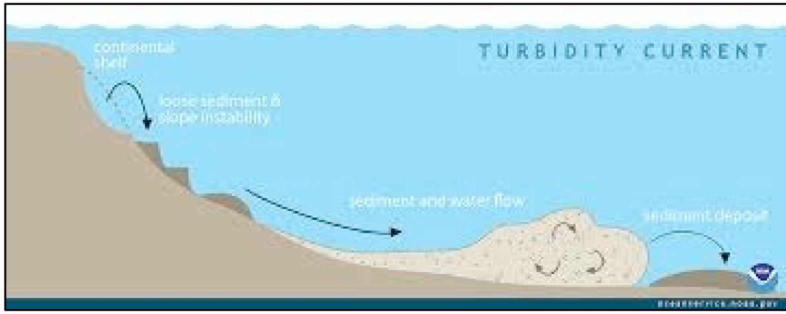


Discovery of Turbidity currents and Turbidites

- The combination of the Newfoundland Tsunami, and early mapping of the ocean floor led to the understanding of Turbidity currents, a type of sediment gravity flow, in 1952.







- In turn, Arnold Bouma described the sequence stratigraphy (Bouma Sequence) , caused by the deposition of turbidity currents in 1962.

4) Turbidity currents

- Density current that flows down slope because of density contrasts between flow and the surrounding fluid.
  - Example: muddy-water vs ocean water.

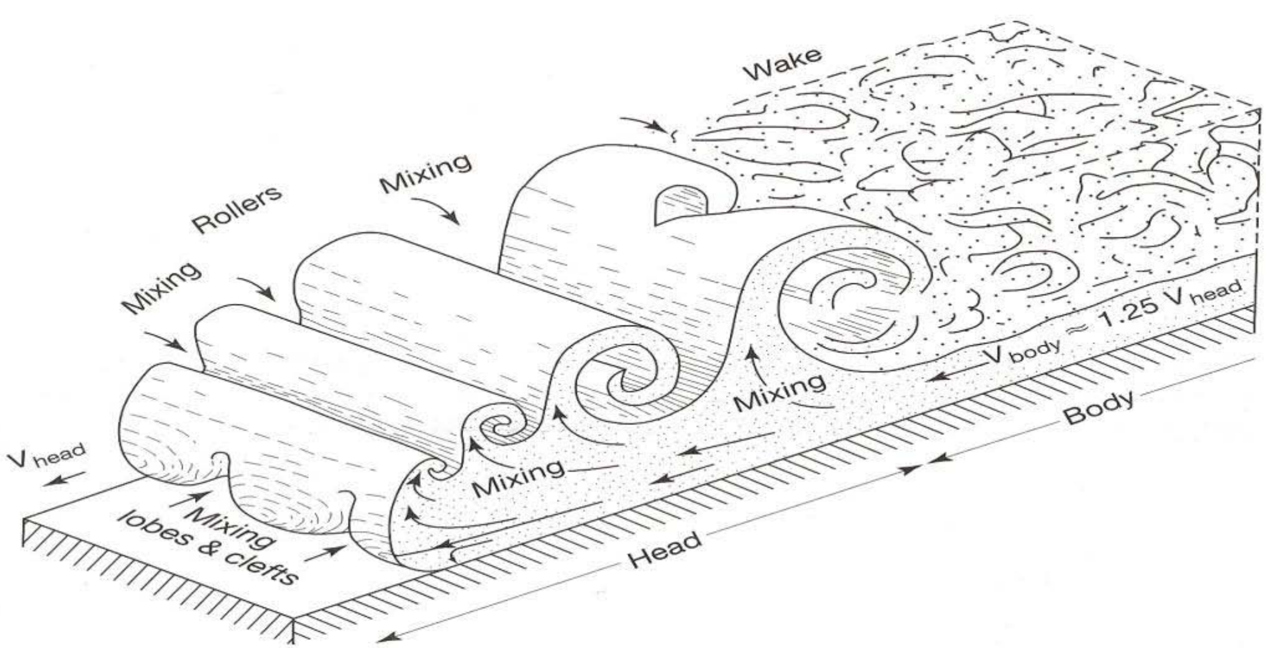
- Frequently initiated by:
  - Input of sediment on the continental slope (from fluvial systems)
  - Input of energy (slump or earthquake)

- Classified as High or Low density flows.
  - Depending on sand component

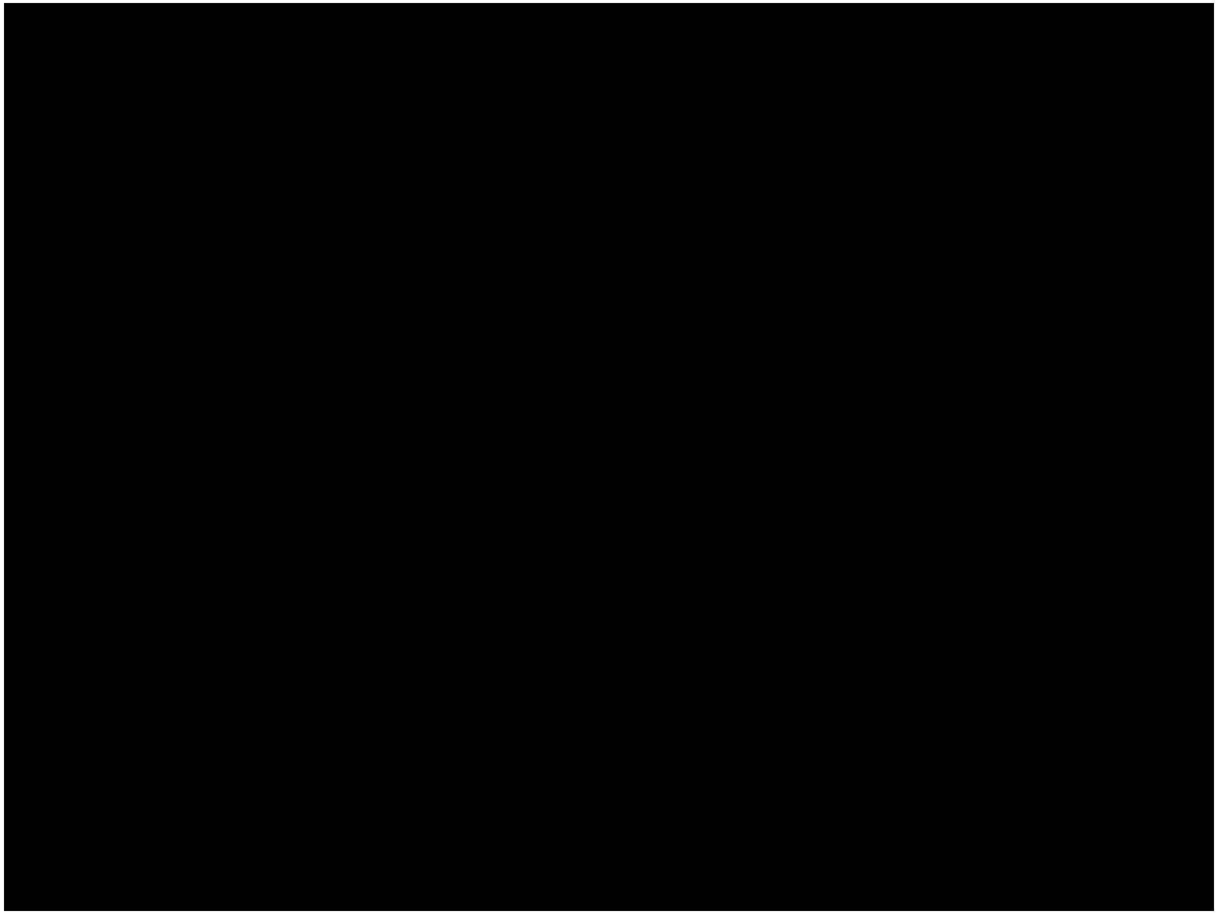
- Well-defined structure with ***Head***, ***Body*** and ***Tail***.

Structure of turbidity currents

- The **head**
  - Twice as thick as the rest
  - Intense turbulence
  - Divided transversely into lobes and clefts
  - Coarser material, may be a region of erosion
- The **body**
  - Flow is nearly steady and uniform in thickness
  - The body flows at a faster velocity than the head
    - Process of mixing
  - Region of deposition
- The **tail**
  - Thins abruptly away from the body and becomes more dilute



Turbidity Current



Video: W. Washington University

Flow velocity of turbidity currents

- The **head**

$$U_{head} = 0.7\sqrt{\frac{\Delta\rho}{\rho}gh}$$

Density contrast

Height of the head

Density of ambient water

- The **body**

$$U_{body} = \sqrt{\frac{8g}{f_0 + f_1}\left(\frac{\Delta\rho}{\rho}\right)hs}$$

Frictional resistance at the upper interface

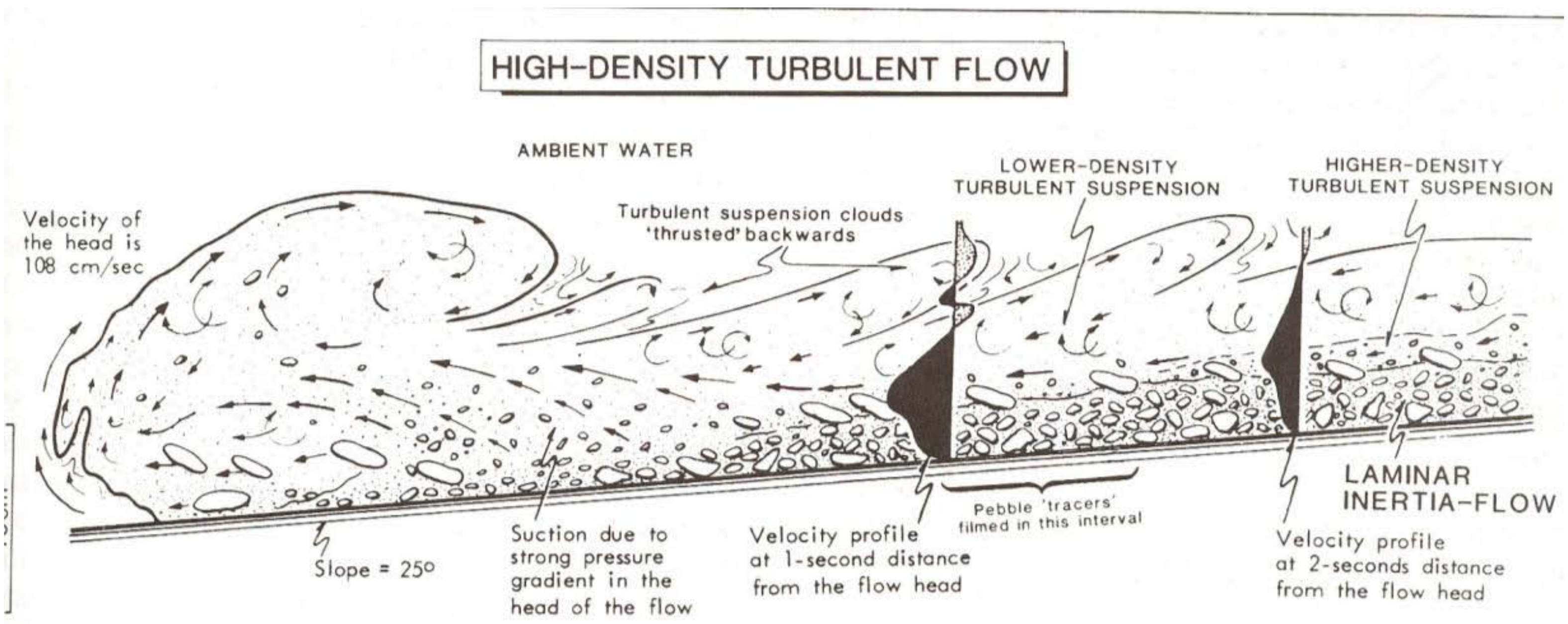
Frictional resistance at the bottom

- Will flow for some time under the action of **gravity** and **inertia**
  - Flow will stop when density contrast is lowered below a critical value due to **particle settling**

Low- and high-density flows

- Low-density flows
  - < 20%-30% grains
  - Clay, silt and fine- to medium sand
  - Suspended entirely by turbulence
- High-density flows
  - >30 % grains
  - May also include coarse-grained sands and pebble- to cobble-size clasts
  - Turbulence and hindered settling from high sediment concentrations
  - The two types may occur along a single current

High-density flows



Source: Benn and Evans (1998)

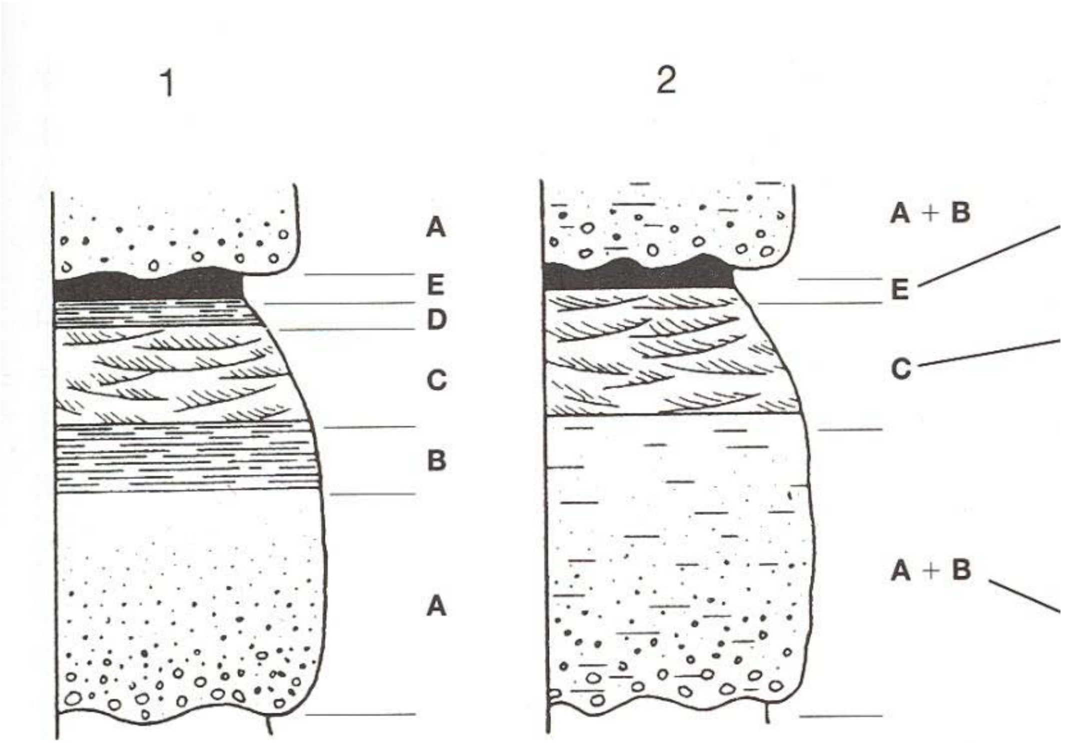
Turbidity currents (steady, uniform type)

- Uniform flows lack a turbulent head
  - Similar velocities as surge-type flows
  - Flow can occur on slope < 1 degree
    - Sediment-laden rivers run into lakes (muddy rivers discharge)
      - Less likely in marine settings owing to lower density contrasts

Turbidity current deposits

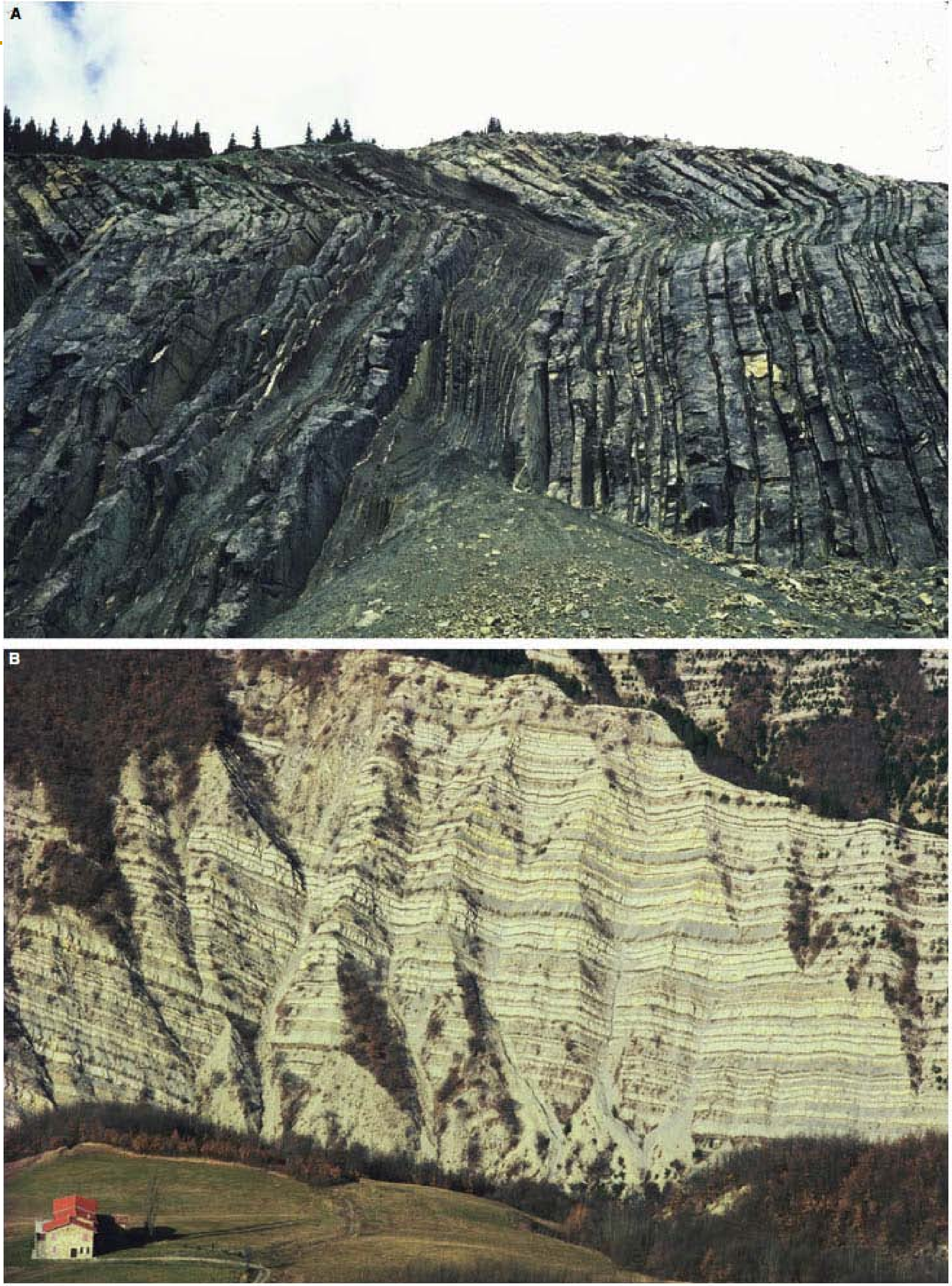
- Turbidites
- Deposited in marine and lacustrine environments.
- Can be classified by their flow type.
  - From high-density flows
    - Thick-bedded turbidite successions (e.g. coarse-grained sandstones)
      - Relatively poor sorting
      - Few internal laminations
      - Basal scour marks are poorly developed
      - May grade upward to finer grained deposits
        - Traction structures (e.g. laminations)
  - From low-density flows
    - Thin-bedded turbidite successions
      - Fine-grained at the base
      - Good vertical size grading
      - Well developed sedimentary structures

The Bouma sequence



Bouma Hsü

Record the decay of flow strength with time
Progressive development of sedimentary structures as flow velocity wanes

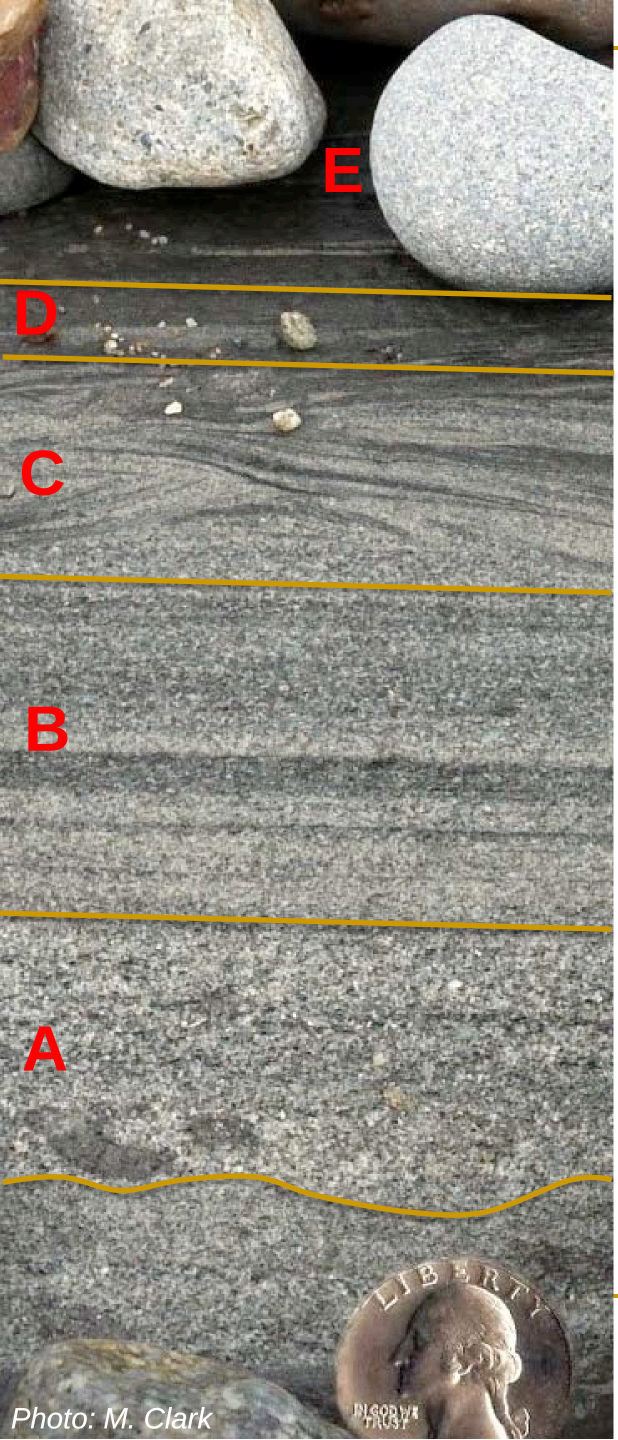


Identification of Turbidites in the geologic record

"Flysch" was term used in the Alps to describe very common and abundant packages of sandstone and mudstone, but the depositional mechanism was poorly understood.

A Ph.D. student named Arnold Bouma connected the newly described turbidity current to Flysch in 1962.

Mutti, 2009



•Hemipelagic sedimentation of fines.

•Laminated fines
•Deposited within the tail of the turbidity current

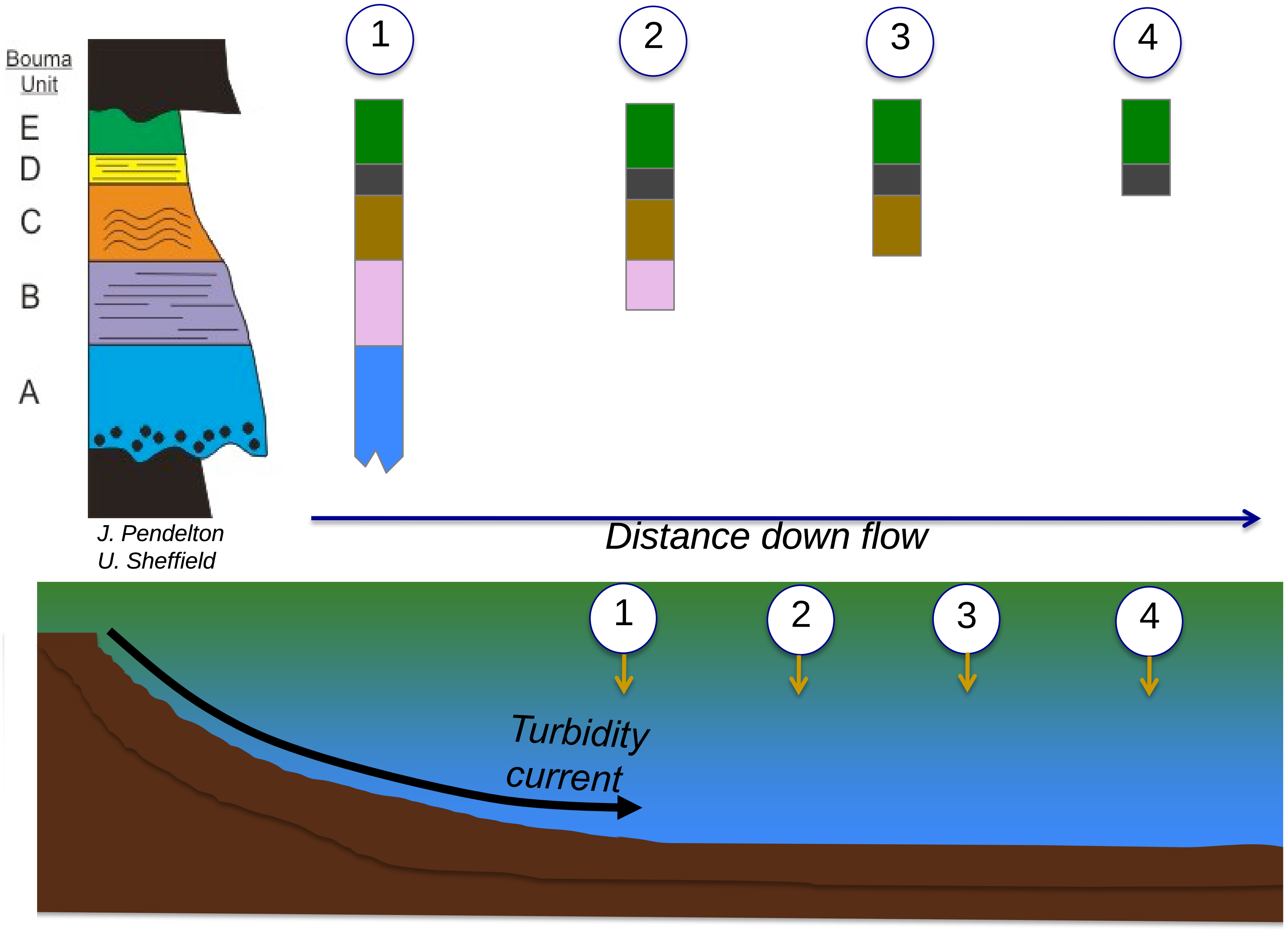
•Cross laminated and rippled sands and fines
•Lower flow regime deposition, can include shearing and dewatering structures

•Parallel laminated coarse – medium sand.
•Results from deposition of traction deposits.

•Massive sand unit coarser at the base, with erosional contact with underlying material. Normal graded bed, with no sedimentary structures
•Results from rapid deposition at the base of the flow

Example of turbidite sequences

Spatial distribution of Units



Arnold Bouma was P. Kuenen's PhD student;
His thesis was to study flysch in southern Europe

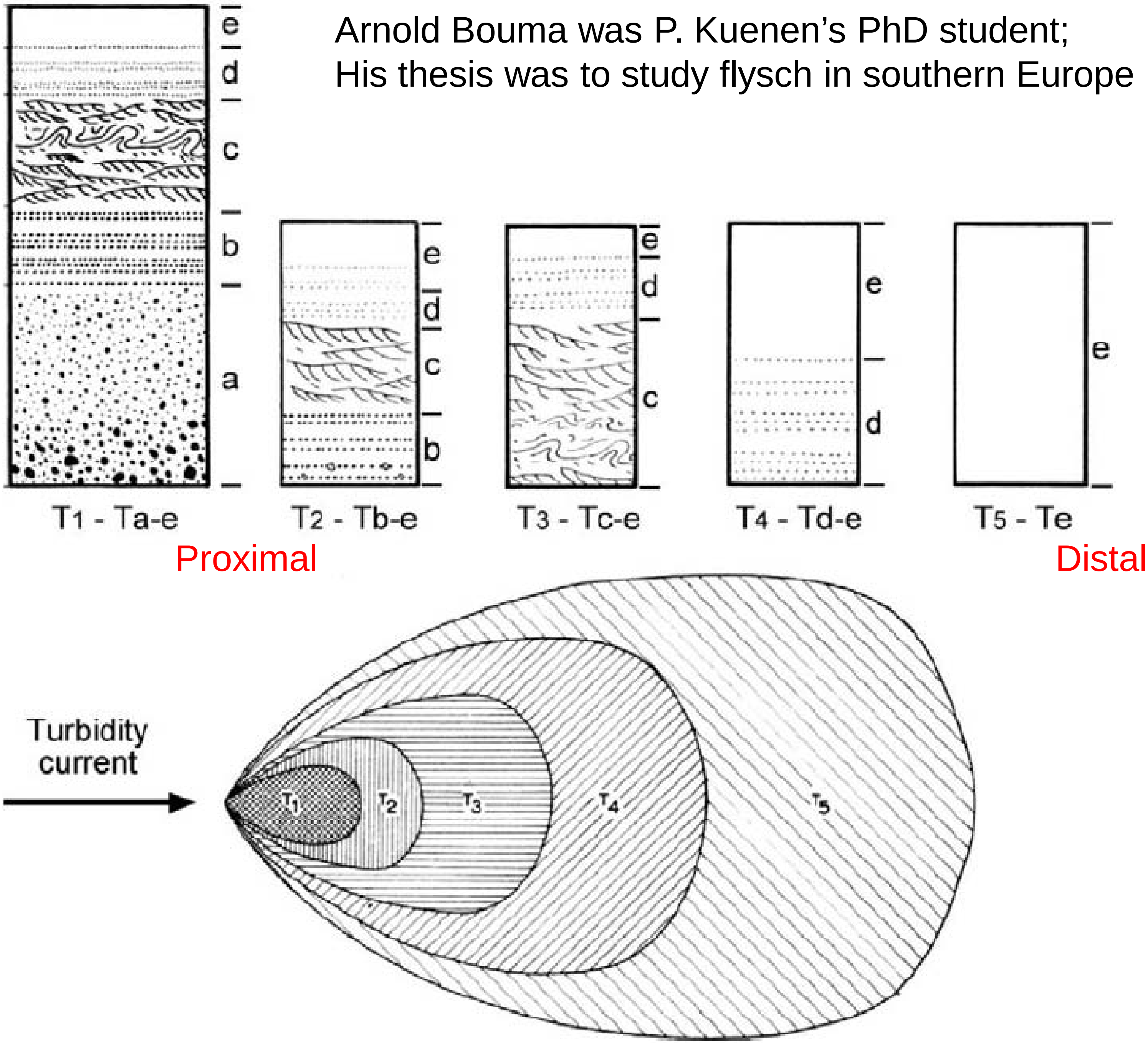


Fig. 8. The Bouma sequence and its 'depositional cone' (from Bouma, 1962).

High Density Flow

Turbidites – from high-density flows

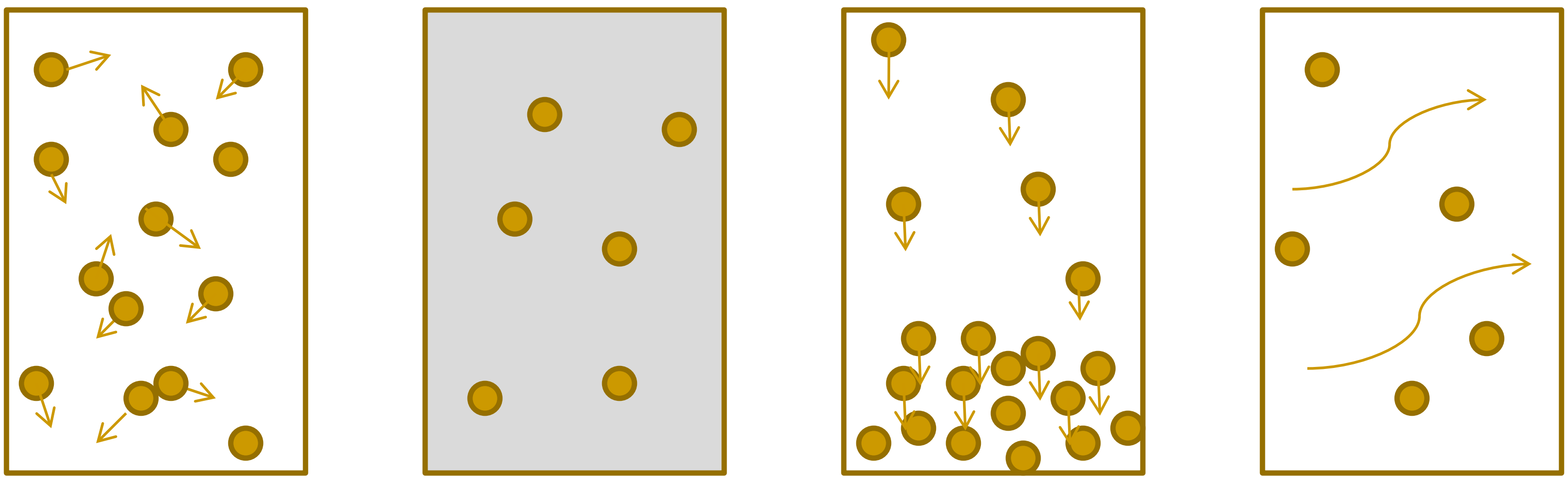
Low Density Flow

Turbidites – from low-density flows

SEDIMENT GRAVITY FLOWS

Summary

Grain flow | *Debris flow* | *Liquefied flow* | *Turbidity flow*



Grain collision | *Matrix strength & buoyancy* | *Buoyancy* | *Turbulence*

Summary: Deposition of Fluid gravity flows