G202 Class Notes - Sedimentary Structures and Sedimentary Environments

I. Basic Concepts

A. Spectrum of Sedimentary Processes
1. Weathering / Erosion (Sediment Creation)
2. Transportation of Sediment
   a. Energy Driven
      (1) Mechanical Energy (Gravity)
   b. Increase energy, increase mass that can be transported
      (1) e.g. boulder transport requires greater system energy that silt
   c. Transportation: Results from critical Energy Thresholds
3. Deposition of Sediment
   a. Transport Energy Decreases below Critical Threshold = "Deposition"
   b. Deposition = "settling"
4. Sedimentary Layering ("Stratification")
   a. Sediments are layered (stratified) through time, due to influence of gravity
5. Sediment Burial
   a. Burial results from continued deposition
      (1) Subsidence and Compaction Through Time
   b. "Sedimentary Basins" = subsiding sediment traps near the Earth's Surface
6. Lithification of Unconsolidated Sediments
   a. Transformation into Sedimentary Rock

B. Sedimentary Environments

1. Surface environments that promote accumulation of sediment
   a. Marine - ocean-related
      (1) Nearshore
         (a) e.g. Beach
      (2) Offshore
         (a) e.g. deep ocean
   b. Nonmarine - terrestrial
      (1) e.g. Rivers, Lakes, Glaciers

2. Sedimentary environments influence style of process, which in turn influences the style of sedimentary deposit

3. Sedimentary Facies
   a. Physical, chemical, and biological characteristics of sedimentary rocks
   b. Sedimentary facies are the "footprint" left by the sedimentary environment
      (1) Reconstruction of ancient sedimentary environments
      (2) "paleogeography" - reconstructing ancient surface systems of the the Earth.

C. Sedimentary Structures

1. Depositional forms in sediment that are preserved in the rock record
   a. e.g. ripple marks, or worm burrows

2. Sedimentary Processes Produce Sedimentary Structures / Sedimentary Structures are used to Reconstruct Sedimentary Process

D. Stratigraphy

1. Study of the spatial and temporal relationships in sedimentary layers or strata

a. 3-D spatial geometry
(1) Vertical vs. Horizontal Stratigraphic Relationships

b. Geologic time perspective: when? how long ago?

(1) Ordering of geologic events through time

II. Basics of Sediment Transportation

A. Energy vs. Mass of Sediment

1. The greater the mass (e.g. grain diameter) of sediment, the greater the energy needed to transport

a. e.g. question: could wind transport a boulder the size of this room?

2. Examples of Sedimentary Processes and Energy Source

a. Flowing Water / Rivers ---- gravity + climate
b. Flowing Glacial Ice ------ gravity + climate
c. Landslide / Rock Fall ------ gravity
d. Wind Blown Sediment ---------climate / air flow

3. Agents of Transportation: gravity, wind, water, ice

a. Energy relates directly to velocity of motion
(1) stream velocity, wind velocity, etc.

B. Methods of Transporting Sediment

1. Suspension - sediment is suspended in the body of the transporting medium
a. e.g. blowing dust in the atmosphere
b. e.g. brown clay and silt in the river after a rain storm

2. Bedload / Traction - sediment is rolled and tumbled at the base of the transporting medium
a. e.g. a cobble rolling along the bottom of a stream

b. Saltation: bouncing of particles via upcurrents, and trajectory fall under force of gravity.

3. Dissolved Load - dissolved ions transported in a fluid medium
   a. e.g. dissolved salt in a river

III. STRATIFICATION

A. Stratification = Horizontal layering of sediment under gravity

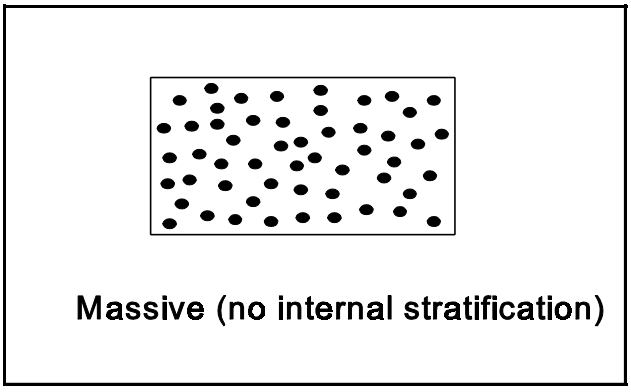
1. Strata = multiple layers of sediment (plural),

2. Beds: Strata greater than 1 cm in thickness,

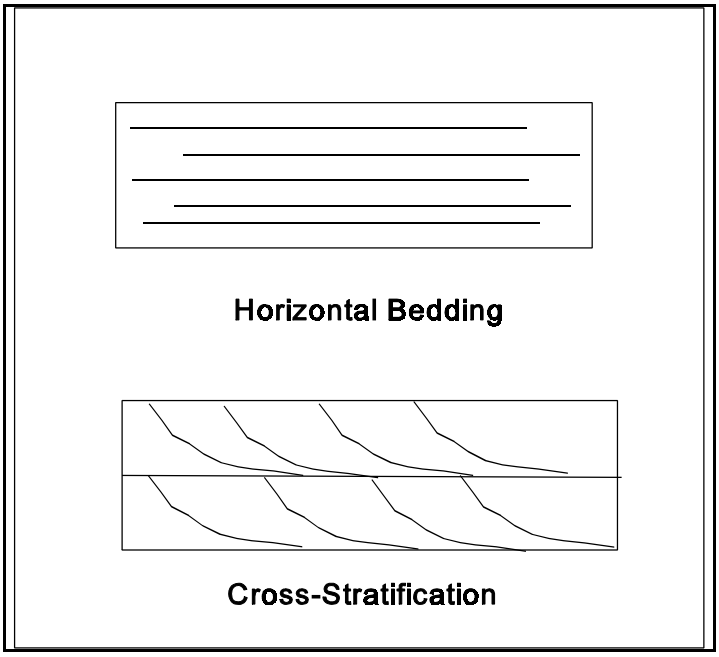
3. Laminae: Strata thinner than 1 cm in thickness

B. Internal Stratification

1. Massive - no evidence of internal layering within a sedimentary rock bed



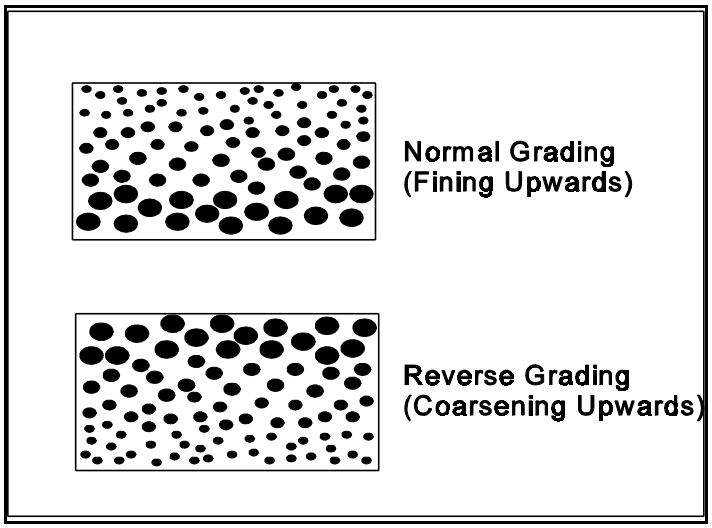
2. Horizontal vs. Cross-Stratified



3. Graded Bedding: a layer of sediment in which particle sizes change systematically in a vertical and/or lateral direction

   a. Normal Grading: fining of grain sizes in an upward direction

   b. Inversely Graded: Coarsening of grain sizes in an upward direction



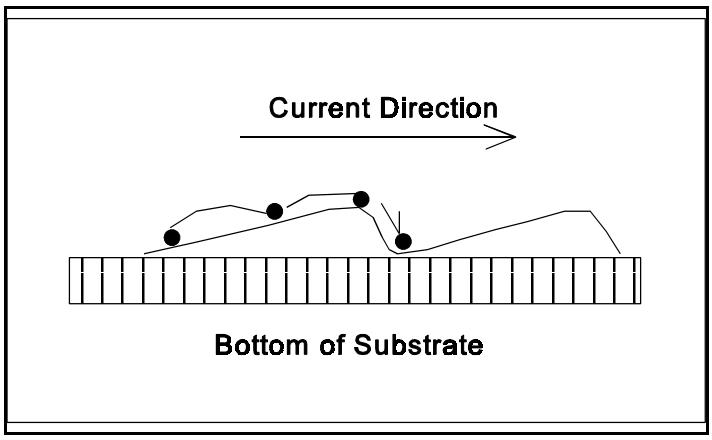
IV. Sedimentary Structures

A. Sedimentary Structures primarily result of physical transportation processes, or biologic processes, or post-depositional processes or chemical processes.

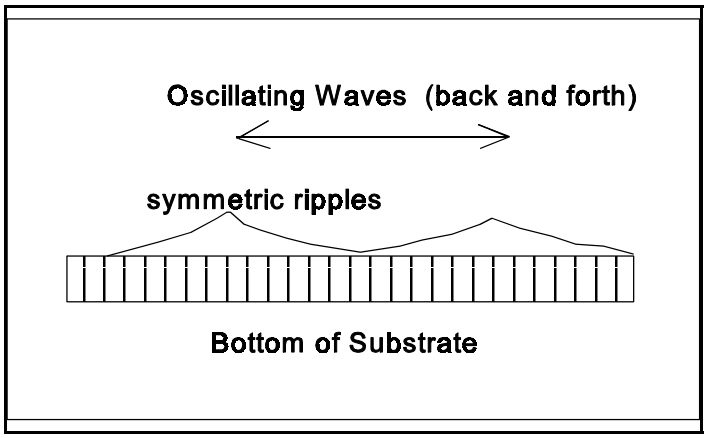
1. Paleocurrents - flowing fluids at the time of deposition mold sediment into characteristic shapes
    a. shapes can provide evidence of the direction of current flow at the time of deposition (maybe millions of years ago!!!).

B. Basic Examples of Sedimentary Structures

1. Asymmetric Current Ripples - flowing water and currents move sediment in small-scale forms know as "ripples" of sediment



2. Symmetric or Oscillation Ripples: symmetrical in cross-sectional form, developed under shallow water conditions within oscillating wave base (lakes or ocean beaches)



3. Sole Marks: sedimentary structures found on the bottom or "soles" of beds, essentially comprised of positive relief casts derived from underlying sediment surface.

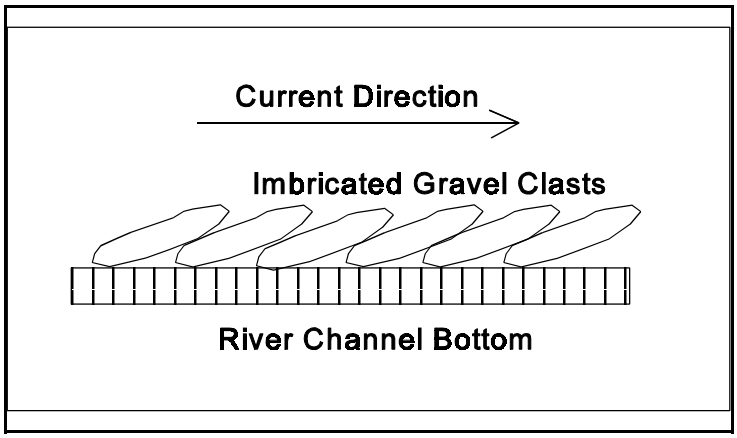
    a. Flute Casts: current-formed erosion structure, bulbous cast formed by scouring of sediment interface, bulbous end generally points up-current.

    b. Load Casts: irregular knobs found on sandstones overlying shale beds.
    c. Tool Marks: groove casts; infilling of mold formed by dragging object across sediment interface

4. Trace Fossils: i.e. Ichnology:

    a. Tracks, trails, burrows
    b. Bioturbation: general mixing of sediment by dirt eaters.

5. Imbricate Structure (Pebbles): under high energy flow conditions pebbles may take on inclined imbricate orientation, with inclination pointing upstream.



6. Mudcracks and Raindrop Imprints: evidence of subaerial exposure of semi-consolidated sediment surface.

    a. Clay shrinks as it dries, results in polygon fractures

V. Sedimentary Environments and Facies Analysis

A. Sedimentary Environments

1. Defined by the complex interaction of physical, chemical and biological conditions under which sediment accumulates.

    a. Characteristics of a given sedimentary environment yield a specific product of sediment and/or sedimentary rock.

B. Sedimentary Products

1. "Facies": a body of sediment or sedimentary rock that display characteristic or distinctive textural, structural and compositional properties.

    a. Facies by definition: readily detectable and discernable characteristics (chemical, physical or biologic).

**A sedimentary facies is the product of the sedimentary environment and its processes

C. Paleoenvironmental Analysis

1. Goal: to reconstruct surface environments of deposition in the geologic past

2. Key Concept: "Law of Uniformitarianism" - the present is the key to the past.

   a. modern day observations can be used to reconstruct ancient geologic environments

3. Importance: Environmental interpretation important for defining the nature and character of resources found in the sedimentary environment (e.g. oil, coal, natural gas)

VI. Principal Environments of Deposition (refer to diagram in text on p. 131)

1. Continental (Nonmarine): Sedimentary environments found in a terrestrial setting

   a. Fluvial: Associated with processes of aqueous fluid flow on land (i.e. stream and river settings)

      (1) Alluvial Fan: characteristic environment found at the front of steep mountain slopes. Sediment laden streams exiting canyon mouth, depositing sediment in cone-shaped fan at front of mountain.

      (2) Braided vs. Meandering Fluvial

   b. Desert (Aeolian): dry climates, general lack of vegetation + high amounts of weathered sediment = wind-dominated sediment transport (sand dune amalgamation)

   c. Lacustrine: lake-related sedimentation, streams and rivers flowing into standing water (feeding lakes), dumping sediment along lake margins, fine quiet water sedimentation and/or organo-chemical deposition

      (1) Evaporite Basins - high evaporation + dry climate results in salt deposits (e.g. Great Salt Lake, Utah)

   d. Glacial: continental/alpine morainal and/or till depositional processes, high amounts of sediment rapidly deposited; outwash processes cross-over into "glacio-fluvial" realm.

2. Marginal Marine: essentially coastal plain sedimentation where terrestrial fluvial environments transition into the marine/ocean environment

   a. Deltaic: environment characterized by fluvial system depositing sediment into standing body of oceanic (and/or lacustrine) water. Sediment accumulation in form of delta.

b. Beach/Barrier Bar: wave-dominated beach processes as rivers deliver sediment to coastal area; waves re-work sediment into beach deposits.

Barrier Bar: Offshore accumulation of sediment, wave dominated on lee side of island, slack-water dominated on landward side of island

c. Estuarine/Lagoonal: similar to lacustrine, only in marginal marine setting, water chemistry is saline, quiet water sedimentation with bio-critter processes abundant.

d. Tidal Flat: low-lying coastal areas heavily influenced by tidal rise/fall of water, tides rework sediment, bio-critter processes abundant.

3. Open Marine
   a. shallow ocean setting
      (1) Shelf: encompasses sand-dominated shelf or carbonate-dominated shelf accumulations
      (2) Organic Reef: biochemical build-up of carbonate structure comprised of living marine organisms, dominated by corals and algae + other critters
   b. Oceanic: i.e. deeper ocean setting
      (1) Slope: steep-gradient slope transitional to shallow-water shelf and deep ocean floor
         (a) Submarine canyons/submarine fan systems
      (2) Deep-ocean Floor
         (a) Abyssal plain, quiet water mud accumulation

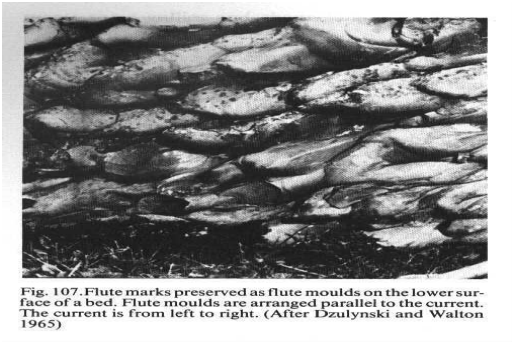


Fig. 107. Flute marks preserved as flute moulds on the lower surface of a bed. Flute moulds are arranged parallel to the current. The current is from left to right. (After Dzulynski and Walton 1965)

Flute Casts

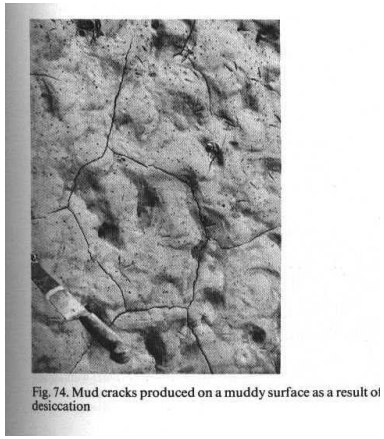


Fig. 74. Mud cracks produced on a muddy surface as a result of desiccation

Mud Cracks

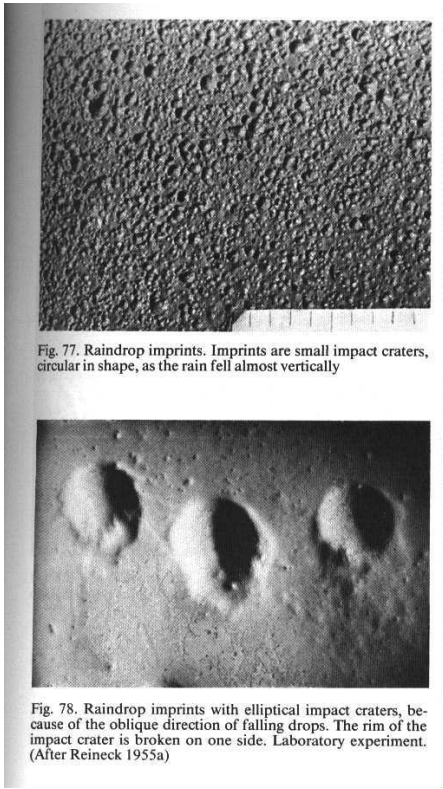


Fig. 77. Raindrop imprints. Imprints are small impact craters, circular in shape, as the rain fell almost vertically

Fig. 78. Raindrop imprints with elliptical impact craters, because of the oblique direction of falling drops. The rim of the impact crater is broken on one side. Laboratory experiment. (After Reineck 1955a)

Rain Drop Impressions

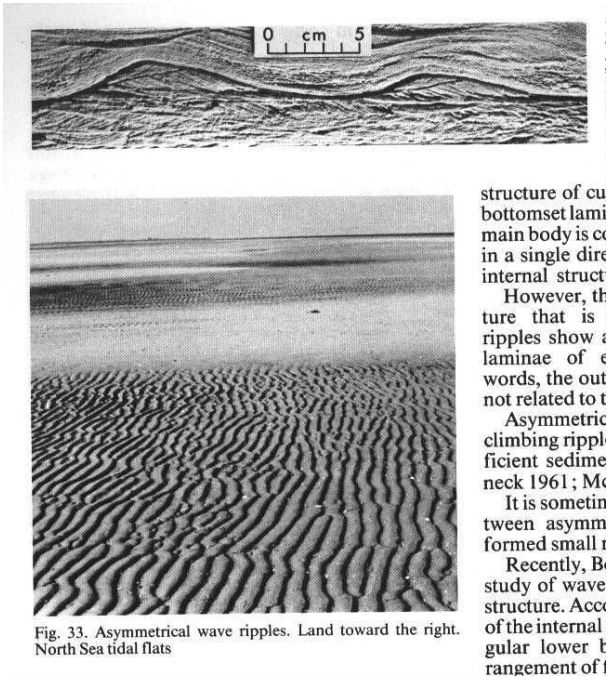


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Fig. 33. Asymmetrical wave ripples. Land toward the right. North Sea tidal flats

Current Ripples (asymmetric)

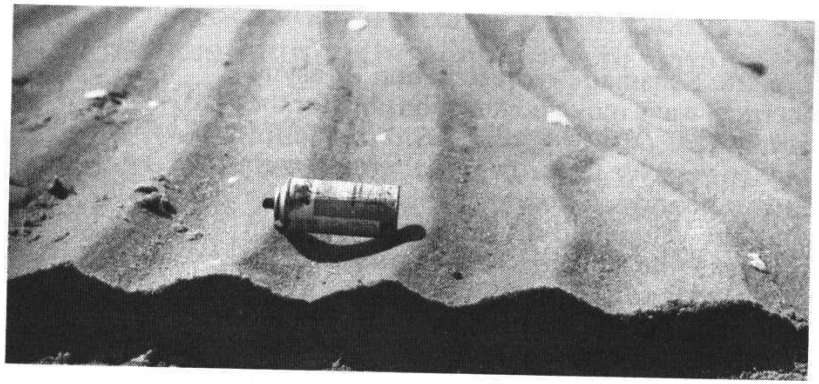

Fig. 28. Symmetrical wave ripples. Tidal flats of the North Sea

Oscillation (Wave) Ripples (symmetric)

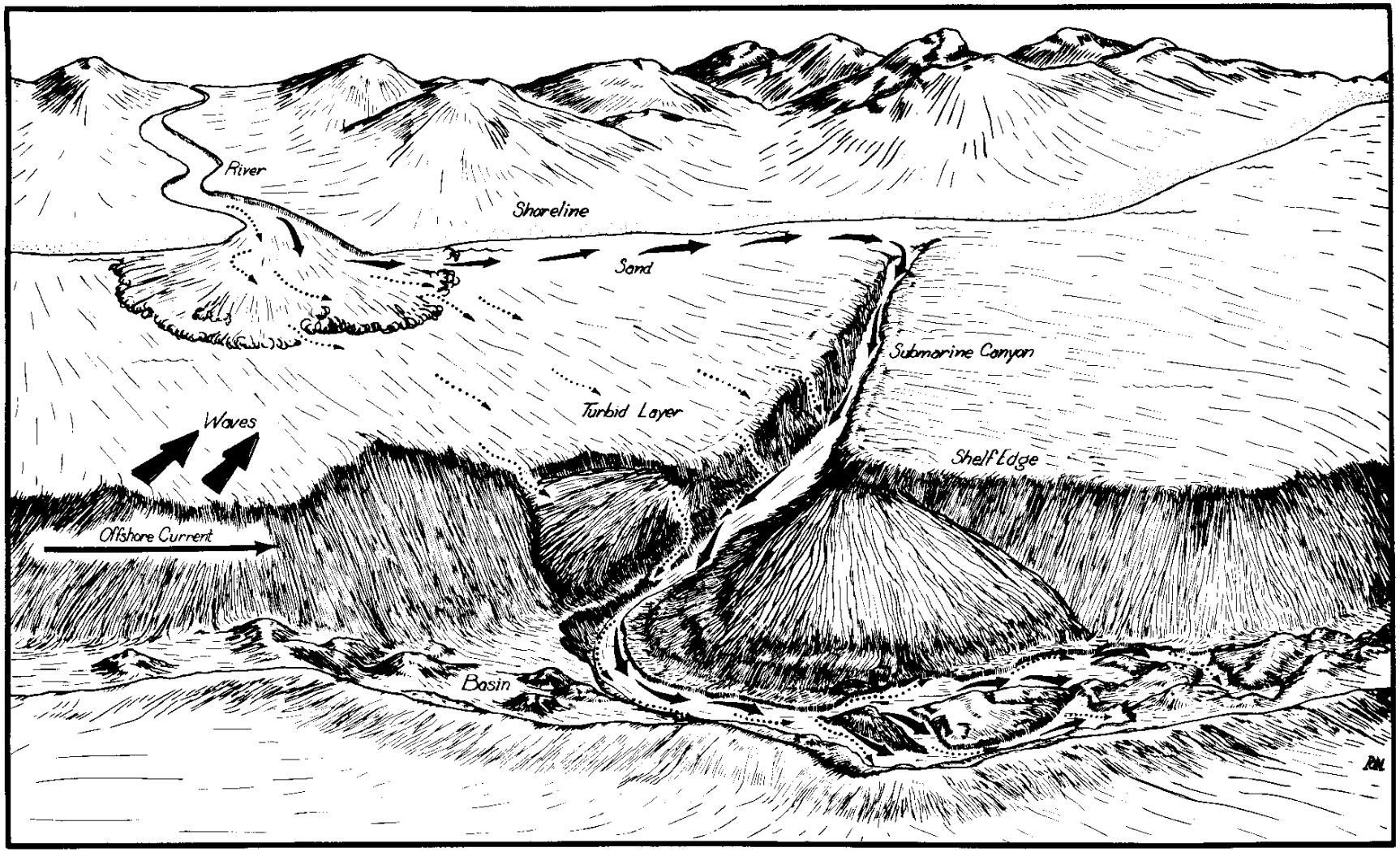

Fig. 636. Schematic representation of the routes of transportation of sand (solid arrow) and mud (dotted arrow) from river mouth to deep-sea basin floor. (After Moore 1969)