Sedimentary Structures
Stratification

Bedding (1-300 cm)

Massive Strata (>300 cm)

Laminations (<1 cm)
Inter-Bed Structures (within strata)

- Graded Beds
- Cross Beds
- Soft Sediment Deformation
- Dropstones

Outcrop of turbidites, Carboniferous, northwestern China.
Graded Beds
Death Valley, CA
Turbidites

1. Initially, all grains are suspended in turbulent water.
2. Larger grains start to settle as energy drops.
3. Fine grains settle last, creating graded bedding.

Submarine canyon, Continental shelf, Turbidity current, Stream carrying sediment.

Turbidites
Graded bedding in a Turbidite
Turbidites
Turbidites
Cross Beds
Zion National Park, UT

1. Wind current direction
   - Continued cross-bed development

2. Cross-bed #1
   - Cross-bed #2
   - Cross-bed #3

3. Cross-bed #3
   - Cross-bed #2
   - Cross-bed #1
Wind current direction

Continued cross-bed development

Cross-bed #1

Cross-bed #2

Cross-bed #1

Cross-bed #3

Cross-bed #2

Cross-bed #1
Crossbedding in rivers and deserts (aeolian)
Soft Sediment Deformation; wet

image credit: Roger Suthren. Bude Formation, Upper Carboniferous, N Cornwall
Soft Sediment Deformation; dry?
Dropstones

Norway
Glaciers are dirty
Sediment Transport and Deposition Associated with Heinrich Events

- Ice Sheet
- Calving Iceberg
- Entrained Sediments
- Basal Sediments
- Glacial Water
- Release of Iceberg Rafted Debris (IRD)
- Turbidites & Debris Flows
- Boundary Current
- Suspended Sediment in Meltwater
- Bedrock

Distance from Ice Margin (km):
- 0-100s
- 1000-4000
Sidetrip:

Paleoclimate:
Heinrich Events
Normal marine sediment: calcareous (CaCO₃ i.e. Calcite) microfossils
Marine sediments during Heinrich events: only lithic fragments, i.e. gravel
Paleoclimate: Heinrich Events
Paleoclimate: Heinrich Events
Paleoclimate:

Heinrich Events

The present, i.e. warm

Last glacial maximum, i.e. cold
Intra-Bed Structures (on the surface of strata)

- Ripple Marks
- Mudcracks
- Raindrop Impressions
- Flute Marks
Ripple Marks

(a) Asymmetric ripples

(b) Symmetric ripples
Turbidites with climbing ripples
Deltaic sediments with wave and current ripples
Mudcracks
Glacier National Park, MT
Raindrop Impressions

Modern raindrop imprints in clay

Robert R. Schrock, Sequence in Layered Rocks, 1948, p. 142
Flute Marks
River channels
River channels
Channel cut into deltaic sediments
Lacustrine (lake) deposits; Eocene Green River Formation, Utah
Sedimentary Structures

Mars - Crossbeds
Fossils
Unaltered Remains
(Usually “younger” fossils)

Amber

2,400yr old
Bog Man, Denmark

Subfossil Wood

Mammoth Hair
“Fossilized” Remains

Replacement

Permineralization

Carbonization
Molds and Casts

Mold - Pennsylvanian Shark’s Jaw

Cast - Paleozoic Crinoid
“Trace Fossils”

*ichnofossils*

**Track**: an impression made by a single foot.

**Trackway**: a number of tracks made during a single trip.

**Trail**: an impression made by a tail or other “non-foot”.

**Feeding tracks**: evidence of food gathering.

**Burrows**: a hole or holes an animal dug into loose sediment (like mud).

**Eggs and Nests**: shells and/or the nests that the babies would have been kept in.

**Coprolites**: poop that has become fossilized.
Trackways and Trails

Fish Fin Marks (Nova Scotia)

Dino Tracks (Connecticut)

Trilobite Trails, New York
505 million years old (Cambrian)
Climactichnites
Climactichnites
Climactichnites; a large slug?
A particularly well defined Cambrian madusae

A resting trace fossil
A medusa: a jellyfish
Tracks and trails
Tracks and trails
6000 year old human footprints preserved in volcanic mud near the lake in Managua, Nicaragua

Tracks and trails
20,000 years ago when humans trekked along the margins of a shallow lake in Australia.

The oldest human footprints (350,000 years ago) have been found in volcanic ash in Italy.

Tracks and trails
Human footprints crossing dinosaur tracks in Cretaceous (>65 million years BP) rocks
Tracks and trails

300 million year old human footprints in rocks from the Carboniferous
Roots in a paleosol (ancient soil)
Rodent Burrows
Worm Burrows

Middle Silurian, Grimsby Formation, Hamilton, Ontario
Dino Nests

*Upper Cretaceous close to KT boundary, Henan province, China*
Miocene Mammal (WA)

Coprolites

Cretaceous Hadrosaur (MT)
Sedimentary Environments
Continental - Fluvial

Figure 5-14
*Earth System History, Second Edition*
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Continental - Glacial
Continental - Desert/Arid
Continental

Lacustrine

Swamp/Bog
Transitional (Coastlines): Beach & Tidal Zone
Transitional: Deltas & Estuaries
Transitional: Tidal Glaciers
Transitional: Barrier Islands
Transitional: Reef & Lagoon
Marine

Shallow Marine

Deep Marine

Monterey deep-sea fan

Delgada deep-sea fan

Arguello deep-sea fan