Laboratory 5

Sedimentary Structures Laboratory

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In this lab you will learn to recognize and identify sedimentary structures. Primary sedimentary structures are those which form during (or shortly after) deposition of the sediment. Some sedimentary structures are created by the water or wind which moves the sediment. Other sedimentary structures form after deposition - such as footprints, worm trails, or mudcracks. Primary sedimentary structures can provide information about the environmental conditions under which the sediment was deposited; certain structures form in quiet water under low energy conditions, whereas others form in moving water or high energy conditions.

TYPES OF PRIMARY SEDIMENTARY STRUCTURES

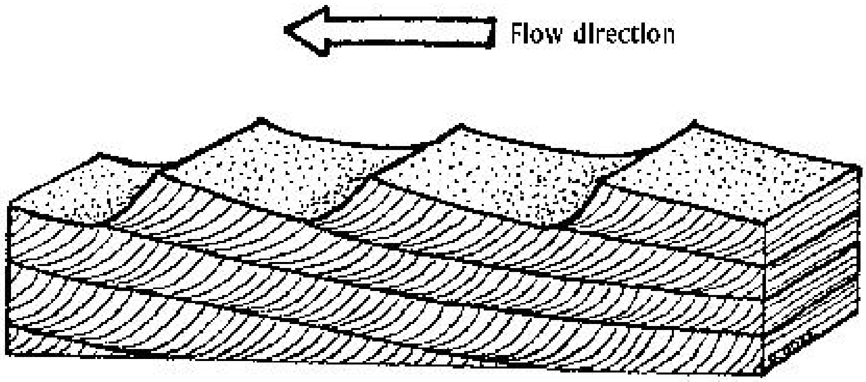
I. INORGANIC SEDIMENTARY STRUCTURES

A. BED FORMS AND SURFACE MARKINGS

Bed forms are features which form on the surface of a bed of sediment. At the time of formation, the "surface of a bed" is equivalent to the sea floor, or the bottom of a lake or river, for example. In a sequence of sedimentary rock, bed forms and surface markings are found on bedding planes.

1. **Ripples** are undulations of the sediment surface produced as wind or water moves across sand. 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. 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. In *waves or oscillating water*, **symmetrical ripples** are produced. Crests of symmetrical ripples tend to be relatively straight, but may bifurcate (or fork).

Asymmetrical Ripples



Asymmetrical ripples and cross-bedding

Asymmetrical ripples on a beach in Australia

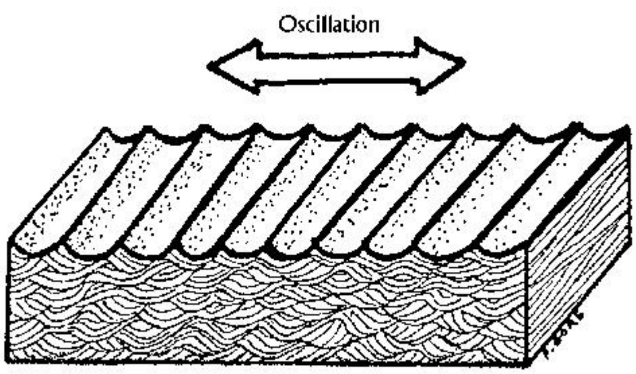
Asymmetrical current ripples, Georgia coast

Asymmetrical lingoid ripples (tongue-like ripples), Georgia coast. Black areas are heavy mineral concentrations.

Asymmetrical rhomboid ripples, Georgia coast

Asymmetrical lingoid ripples.
Paleozoic of northwestern Georgia.

Symmetrical Ripples



Symmetrical wave ripples and wave ripple cross-stratification

Symmetrical wave ripples, Georgia coast

Symmetrical wave ripples
and wave-ripple cross-stratification in
Triassic lakebeds from the Culpeper Basin, Virginia

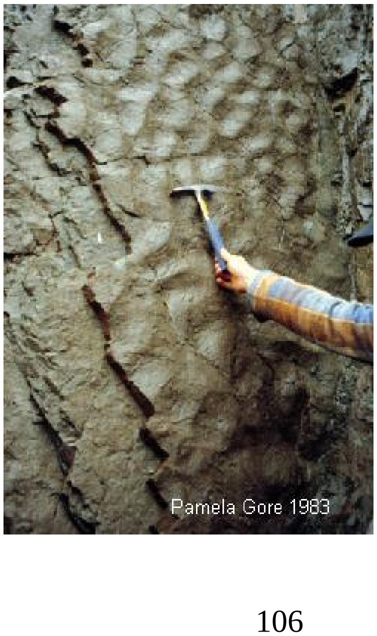
Symmetrical wave ripples, Triassic Culpeper Basin, Virginia

Interference Ripples

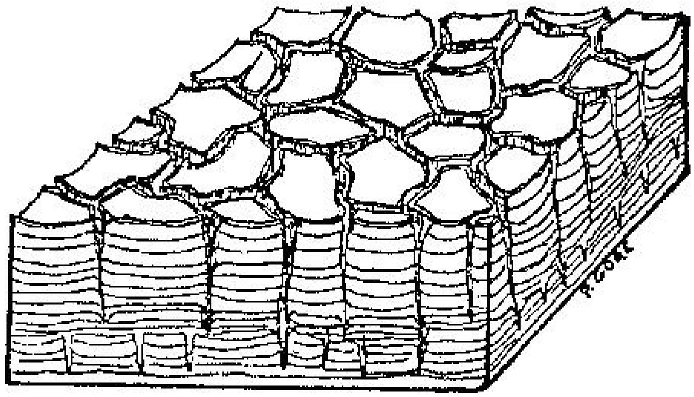
Interactions between waves and currents may produce a more complex pattern of **interference ripples**.

Interference ripples on the Georgia coast; south end of Jekyll Island. These ripples are produced by the interaction of waves and currents in the ridge and runnel system at the beach.

Interference ripples in Paleozoic rocks in the Appalachian Valley and Ridge Province of northwestern Georgia



2. **Mudcracks** are a polygonal pattern of cracks produced on the surface of mud as it dries. The mud polygons between the cracks may be broken up later by water movement, and redeposited as intraclasts (particularly in lime muds).



Mudcracks

Recent mudcracks in a quarry near Frederick, Maryland

Triassic mudcracks in a quarry in Culpeper, Virginia

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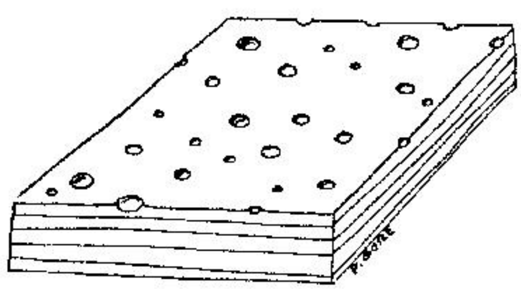
3. **Raindrop prints** are circular pits on the sediment surface produced by the impact of raindrops on soft mud.

RAINDROP PRINTS

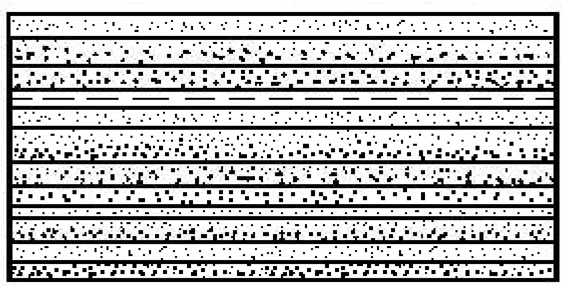


Raindrop prints (foreground) with ripples and bird tracks

B. INTERNAL BEDDING STRUCTURES

These are sedimentary structures which are best seen looking at a side view of a sedimentary rock or sequence of sedimentary rocks.

1. **Stratification** (or layering) is the most obvious feature of sedimentary rocks. The layers (or strata) are visible because of differences in the color or texture of adjacent beds. Strata thicker than 1 cm are commonly referred to as **beds**. Thinner layers are called **laminations** or **laminae**. The upper and lower surfaces of these layers are called **bedding planes**.



Laminations

Laminations on a beach,
St. Simons Island, Georgia

Stratification (also called bedding) in Paleozoic rocks in the Red Mountain road cut, Birmingham, Alabama

Varves are a special type of lamination which forms in glacial lakes. Varves represent deposition over one year, and their formation is related to seasonal influences. Varves are generally graded, with the coarser material at the bottom (silt or sand) representing the spring and summer meltwater runoff, and the finer material at the top representing slow settling of clays and organic matter from suspension during the winter months when the lake is covered with ice. Counting of varves in the geologic record has been used to measure the ages of some sedimentary deposits.

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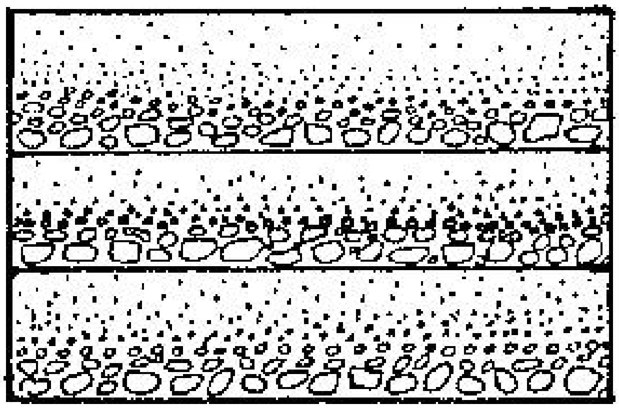
2. **Graded bedding** results when a sediment-laden current (such as a **turbidity current**) begins to slow down. The grain size within a graded bed ranges from coarser at the bottom to finer at the top. Hence, graded beds may be used as "up indicators".

Graded bedding in a bottle, resulting from the settling of sediment.
Photo by Pamela Gore, 2008.



Graded bedding

Graded bedding, New Jersey

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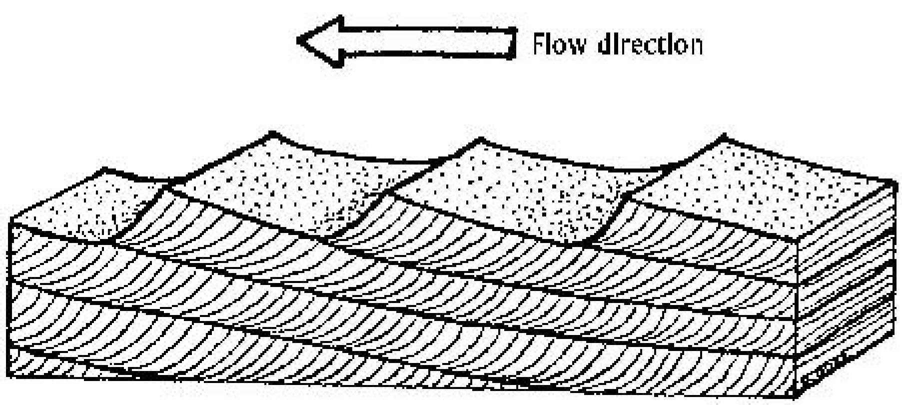
3. **Cross-stratification** is a general term for the internal bedding structure produced in sand by moving wind or water. If the individual inclined layers are thicker than 1 cm, the cross-stratification may be referred to as **cross-bedding**. Thinner inclined layering is called **cross-lamination**.

   Cross-stratification forms beneath ripples and dunes. The layering is inclined at an angle to the horizontal, dipping downward in the down-current direction. Hence, cross-beds may be used as paleocurrent indicators, or indicators of ancient current flow directions. Cross-beds usually curve at the bottom edge, becoming tangent to the lower bed surface. The upper edge of individual inclined cross-beds is usually at a steep angle to the overlying bedding plane. Hence, cross-beds may also be used as "up indicators".



Asymmetrical ripples and cross-bedding

Cross-stratification in a beach cut, Jekyll Island, Georgia

Large scale cross-bedding in Triassic dune sands, Bay of Fundy, Nova Scotia, Canada

Cross-stratification in an outcrop of upper Paleozoic rocks in Birmingham, Alabama

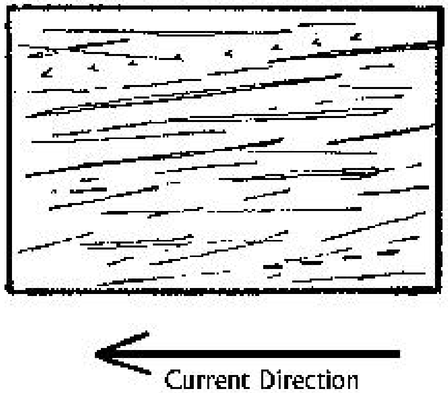
Cross-stratification, Dug Gap, Georgia

C. SOLE MARKS

Sole marks are bedding plane structures preserved on the bottom surfaces of beds. They generally result from the filling in of impressions made into the surface of soft mud by the scouring action of the current, or by the impacts of objects carried by the current. If sand is deposited later over the mud, filling in these structures, they will be preserved in relief on the bottom of the sandstone bed. (These structures are not usually seen on the surfaces of shale beds because they tend to weather away.)

1. **Tool marks** are produced as "tools" (objects such as sticks, shells, bones, or pebbles) carried by a current bounce, skip, roll, or drag along the sediment surface. They are commonly preserved on the lower surfaces of sandstone beds as thin ridges. Tool marks are generally aligned parallel to the direction of current movement.

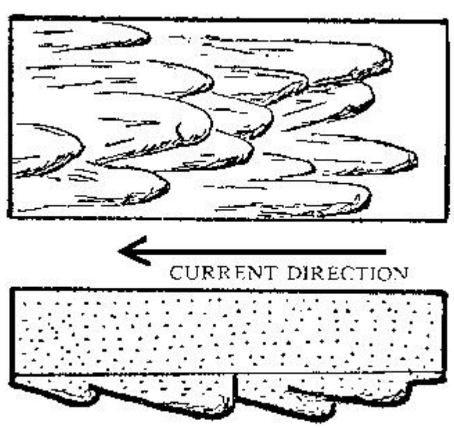
TOOL MARKS



Tool marks in shale, Kentucky. Photo by Pamela Gore.

2. **Flute marks** are produced by erosion or scouring of muddy sediment, forming "scoop-shaped" depressions. They are commonly preserved as bulbous or mammillary natural casts on the bottoms of sandstone beds. Because of their geometry, flute marks (also called flute casts) can be used to determine paleocurrent directions.

FLUTE MARKS



II. ORGANIC OR BIOGENIC SEDIMENTARY STRUCTURES

Organic or biogenic sedimentary structures are those which are formed by living organisms interacting with the sediment. The organisms may be animals which walk on or burrow into the sediment, or they may be plants with roots which penetrate the sediment, or they may be bacterial colonies which trap and bind the sediment to produce layered structures.

A. Trace fossils or ichnofossils

Trace fossils or ichnofossils include tracks, trails, burrows, borings, and other marks made in the sediment by organisms. They are **bioturbation structures** formed as the activities of organisms disrupt the sediment. As organisms tunnel through sediment, they destroy primary sedimentary structures (such as laminations) and produce burrow marks. Bioturbation continuing over a long period of time will thoroughly mix and homogenize the sediment. Through this process, laminated sediment can be altered to a massive, homogeneous sediment with no readily discernable layering or other sedimentary structures.

1. **Tracks** or footprints are impressions on the surface of a bed of sediment produced by the feet of animals. Examples include dinosaur footprints or bird tracks. In some cases, tracks are found as sole marks on the bottoms of beds, where sediment has infilled the tracks, and preserved them as casts.

   A **trackway** is a line of tracks showing the path along which an animal walked (as opposed to an isolated footprint).

Dinosaur tracks,
Dinosaur State Park,
Rocky Hill, Connecticut

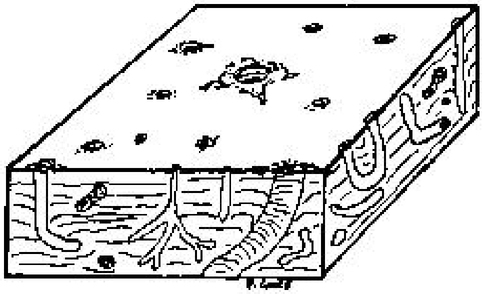
Modern raccoon trackway, North Carolina

2. **Trails** are groove-like impressions on the surface of a bed of sediment produced by an organism which crawls or drags part of its body. Trails may be straight or curved.

Trails
Climactichnites,
505 million years old, Late Cambrian, New York

Trails, Triassic, Culpeper Basin, VA

3. **Burrows** are excavations made by animals into soft sediment. Burrows may be used by organisms for dwellings, or may be produced as a subterranean organism moves through the soil or sediment in search of food. Burrows are commonly filled in by sediment of a different color or texture than the surrounding sediment, and in some cases, the burrows may have an internally laminated backfilling. Burrow fillings may become cemented and hard, weathering out of the rock in rope-like patterns.



Several types of burrows, including branching, U-shaped, and vertical

Burrows surrounded by pellets, Georgia coast

Burrows in Triassic rocks, Deep River Basin, North Carolina

*Left = **Zoophycos** burrows in limestone, Kentucky*
*Right = **Skolithos** worm burrows in quartzite. Cambrian Weverton Quartzite, Harpers Formation, or Antietam Formation. Cross-stratification and laminations about 1 cm thick are present in some of the samples. Stream cobbles found in Henson Creek, Prince Georges County, Maryland.Scale in centimeters and inches. Image courtesy of A. O'Neil.*

4. **Borings** are holes made by animals into hard material, such as wood, shells, rock, or hard sediment. Borings are usually circular in cross-section. Some snails are predators and produce borings or "drill holes" into other molluscs, such as clams, to eat them. Another mollusc, known as the "shipworm", drills holes into wood. Sponges also produce borings, commonly riddling shells with numerous small holes.

*Boring in **Arca** bivalve shell, produced by carnivorous moon snail, **Lunatia** or **Polynices**. Note the conical, tapering shape of the hole, like a countersunk hole for a screw.*
Photo by Pamela Gore.

Borings in bivalve shells, St. Augustine, FL

Borings in fossil giant oyster produced by Clionid sponge

5. **Root marks** are the traces left by the roots of plants in ancient soil zones (called paleosols). Rootmarks typically branch downward in a pattern resembling an upside-down tree. Root marks are sometimes gray or greenish, penetrating reddish-brown paleosols. This contrast in color can make them easy to see and identify.

Rootmarks in the Triassic Deep River Basin,North Carolina

B. Biostratification structures

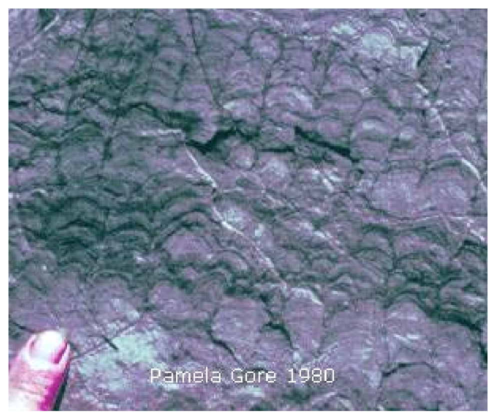
Biostratification structures are sedimentary layers produced through the activities of organisms. Stromatolites are the only type of biostratification structure we will study.

1. **Stromatolites** are mound-like structures formed by colonies of sediment-trapping cyanobacteria (commonly called blue-green algae). These organisms inhabit some carbonate tidal flats, and produce dome-like laminations in lime mud (fine-grained limestone or micrite).

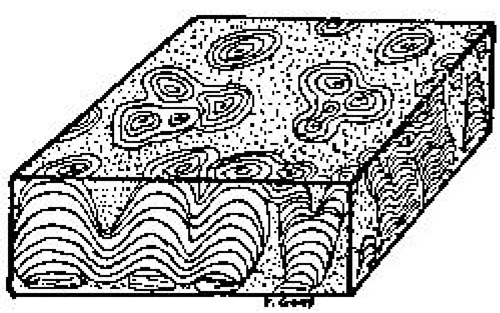
   Stromatolites are "organo-sedimentary structures", and not fossils because they contain no recognizable anatomical features.

   Stromatolites form today in only a few places in the world, primarily in hypersaline environments (such as Shark Bay, Australia), and a few freshwater carbonate- precipitating lakes. In the geologic record, most stromatolites are found in Precambrian and lower Paleozoic limestones. The cyanobacteria which formed these stromatolites were photosynthetic, and they are therefore responsible for changing the character of the Earth's atmosphere from one dominated by carbon dioxide to one with significant quantities of free oxygen.

Stromatolites,
Ordovician, western Maryland



Digitate (finger-like) stromatolites,
Ordovician, western Maryland


Stromatolites

DETERMINING "UP DIRECTION"

When you examine a sequence of beds which has been tectonically deformed and possibly overturned, it is necessary to determine the "*up direction*". This is done by studying the sedimentary structures for clues.

Sedimentary structures such as graded beds, cross beds, mudcracks, flute marks, symmetrical (but not asymmetrical) ripples, stromatolites, burrows, tracks, and other structures can be used to establish the original orientation of the beds. (Fossils can also be used to establish up direction, if they are present in the rock in “life position”.)

Carefully examine the sedimentary structures in <u>any</u> dipping sedimentary sequence, because the rocks can be *overturned* by tectonic forces, and what initially appears to be younger because it is on top, may in fact turn out to be at the bottom of the section!

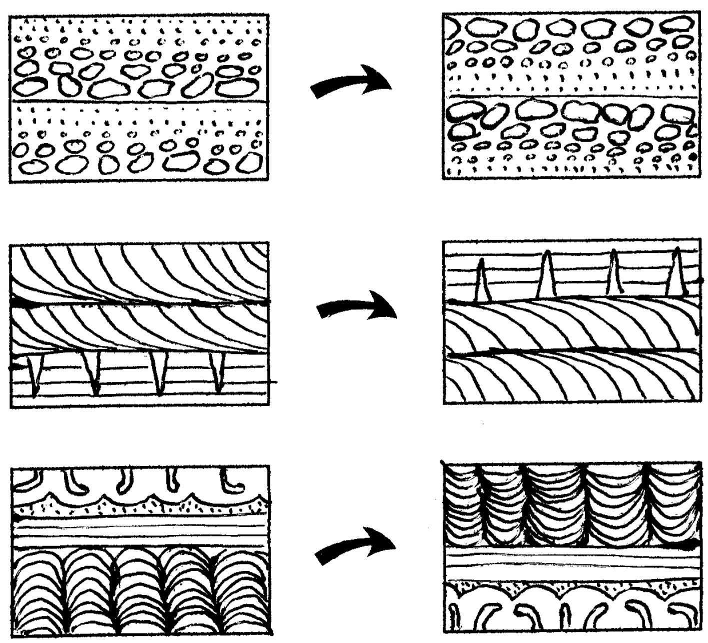


Illustration of overturned beds.
Left column = right-side-up
Right column = upside-down

Summary

The following list is a summary of the sedimentary structures mentioned in this lab:

I. Inorganic sedimentary structures

- A. Bedforms and surface markings
  1. Ripples
     - Asymmetrical ripples (including lingoid and rhomboid ripples)
     - Symmetrical ripples
     - Interference ripples
     -
  2. Mudcracks
  3. Raindrop prints
- B. Internal bedding structures
  1. Stratification (strata)
     - Beds
     - Laminations or laminae
     - Varves
  2. Graded bedding
  3. Cross-stratification
     - Cross-bedding (cross-beds)
     - Cross-lamination
- C. Sole marks
  1. Tool marks
  2. Flute marks

II. Organic or biogenic sedimentary structures

- A. Trace fossils or ichnofossils
  1. Tracks
  2. Trackways
  3. Trails
  4. Burrows
  5. Bioturbation
  6. Borings
  7. Rootmarks
- B. Biostratification structures
  1. Stromatolites

Laboratory 5

Sedimentary Structures Exercises

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Pre-Lab Exercises

Do these exercises before you come into lab, and have them ready to turn in.

1. Matching. Match the sedimentary structure with the environment in which it is most likely to be found. Put the letter in the blank.

	Sedimentary structure	**Possible Environment**
1. _____	Mudcracks	a. turbidity currents
2. _____	Stromatolites	b. dried up lake
3. _____	Symmetrical ripples	c. glacial lake
4. _____	Asymmetrical ripples	d. tidal flat
5. _____	Graded bedding	e. river
6. ____	Varves	f. wave-washed shoreline

2. Which of the **sedimentary structures** in this lab may be useful in determining paleocurrent directions? (List 4 different structures.)

____________________ ____________________

____________________ ____________________

3. Which of the **sedimentary structures** in this lab may be useful in helping determine the top from the bottom of a bed ("up indicators")? (List 4 different structures.)

____________________ ____________________

____________________ ____________________

4. Place an X in the table for the environments in which the sedimentary structure may form.

Sedimentary structure	River	Shallow sea	Beach	Tidal flat	Dry lake bottom	Sand dunes (wind)	Deep Sea
Laminations							
Asymmetrical ripples							
Symmetrical ripples							
Mudcracks							
Raindrop prints							
Cross-stratification							
Graded bedding							
Tracks							
Burrows							
Stromatolites							

Lab Exercise

Using the sedimentary structures provided in the lab, fill in the chart below.

Sample	Inorganic or Biogenic?	Rock Type	Describe the environment of deposition	Name of Sedimentary Structure
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

12				
13				
14				
15				

Online students see additional Sedimentary Structures exercises here:
http://facstaff.gpc.edu/~pgore/geology/historical_lab/sedstr.htm.