**GEOLOGIC HISTORY LAB PAIR**

Kathleen Gilbert, Maria Waller, Rebecca Mattison

Wellesley College, Wellesley, MA

**LAB A—Depositional Environments and Fossils**

A sedimentary rock forms completely at the earth’s surface and therefore records information about the earth’s environment at the time and place the rock formed, its *depositional environment.* This makes sedimentary rocks very useful tools for interpreting earth history. During this week’s lab, we will work on recognizing and interpreting the features in sedimentary rocks that help us unravel the rock’s depositional environment.

To begin, review what you know about sedimentary rocks.

There are 2 types of sedimentary rocks.

1. Clastic Sedimentary Rocks – Rocks that form from an accumulation of material that originates and is transported as solid particles (or grains).
2. Chemical Sedimentary Rocks – Rocks that form from material produced by chemical weathering. Dissolved substances are precipitated by inorganic or organic processes.

**Clastic Sedimentary Rocks** – include such rocks as shale, sandstone, conglomerates.

Grain size is the primary way to distinguish one clastic sedimentary rock from another.

Sorting and rounding are also used to describe these rocks and classify them further.

Sorting – distribution of particle size, ranging from well-sorted to poorly sorted

 Well-sorted – all the same size particles

 Poorly-sorted – many size particles

Rounding – whether a rock is angular or rounded, or somewhere in between.

Degree of Sorting- gives information about the deposition of the sediments. Wind deposits are better sorted than ocean deposit, which are better sorted than stream deposits, which are better sorted than glacial deposits.

Degree of Rounding – the shape of the grains give us information on the history of transport. Grains are rounded during transport, either airborne or by water. The degree of rounding indicates the distance or time of transport.

**Chemical Sedimentary Rocks** – include rocks such as limestone, chert, and rock salt, which are formed through;

 Biochemical origin – organic processes of water-dwelling organisms, or

Inorganic processes – evaporation and chemical activity, such as dripstone in caves and salt evaporated from seawater.

Chemical sedimentary rocks are primarily identified by mineral composition.

**Depositional environments:**

The depositional environment of a sedimentary rock is the environment at the earth’s surface at the time that rock formed. Some examples of possible depositional environments are:

 river channel desert sand dune beach and many others….

 flood plain swamp deep marine

Below are some general descriptions of some of the depositional environments we will be working with during lab today.

Continental Environments –

**Streams** (also called rivers, fluvial) erode transport and deposit more land material than any other process in the continental environment. Streams deposit sediment within their channels, but also on their floodplains when flood waters flow out of the stream channels. The stream channel deposits tend to be medium to coarser-grained and the floodplain deposits are usually finer-grained sediment.1

In some high latitude and high altitude regions where it is cold enough to have **glaciers**, they are the important source of deposition and erosion. Glaciers erode and transport huge volumes of sediment of all sizes. Ice directly deposits a wide range of sized particles. Meltwater streams coming off of the glaciers transport the material away from the glacier. These deposits become better sorted the farther they are transported.1

In arid regions and some coastal locations, **wind** is the important process. Wind deposits are well-sorted because wind transports the smaller sized particles, and therefore similar-sized particles. These sediments can be transported great distances. Where winds are strong and sediment is not anchored by vegetation, wind can travel close to the ground and accumulate as dunes. These occur in beach and desert environments.1

Playa lakes occasionally form in desert environments after heavy rains or snowmelt. The water evaporates quickly leaving behind **evaporites** (gypsum, halite).1

Marine Environments –

Marine environments are divided according to water depth. The **shallow marine** reaches approximately 200 meters deep. It extends from the shore to the outer edge of the continental shelf. The **deep marine** environment is seaward of the continental shelf in waters deeper than 200 meters. 1

The **shallow marine** environment is made up of the **continental shelf**, which is a gently sloping submerged surface extending from the shoreline toward the deep-ocean basin. The continental shelf varies in width from almost non-existent to 1500km wide. The average width is 80 km.2

The kind of sediment deposited on the continental shelf depends on several things. These include distance from shore, the elevation of the land area, water depth, water temperature, and climate. Due to the ongoing erosion of the adjacent continent, the shallow marine environment receives huge quantities of land-derived sediment. 1 Rivers deliver most of the sediments to mid-latitude shelves. Therefore, grain size routinely decreases with distance from shore; sediment sorting also tends to be rather good. Shallow water, nearshore sediments form thick sand blankets with abundant ripple marks. As depth increases and water movement decreases, average grain size decreases, and sand, silt, and clay occur interbedded. In water depths greater than 150-200 ft (45-60 m), even [storm](http://science.jrank.org/pages/6531/Storm.html) waves do not stir the bottom; consequently, silts and clays predominate. Scattered sand deposits are also located on outer shelf margins. During periods of lower [sea level](http://science.jrank.org/pages/6014/Sea-Level.html), rivers flowing across what is now the inner shelf deposited these so-called relict sediments.3

If the influx of sediments from the land is small and the seas are relatively warm, carbonate-rich muds may be the predominant sediment. Most of the carbonate material consists of carbonate shell debris and inorganic precipitates. 1 At low latitudes, bottom-dwelling plants and animals secrete large volumes of [calcium carbonate](http://science.jrank.org/pages/1121/Calcium-Carbonate.html), producing thick blankets of carbonate sediment. 3 Coral reefs are associated with warm, shallow marine environments.1 Corals produce a rigid framework of carbonate rock (limestone), which is also a major source of sediment of various grain sizes. Where stream input is great, terrigenous sediments discourage habitation by carbonate-producing organisms and dilute any carbonate sediment that is produced. 3

In hot regions where the sea is located in a restricted basin, evaporation can trigger the precipitation of **evaporites** (gypsum, halite). 1

**Deep Marine** environments include all the floors of the deep ocean. Sediment from landmasses does not reach this environment, and so tiny particles from many sources slowly accumulate on the seafloor. One of the sources of particles are planktonic animals that produce either a calcium carbonate or a silica shell. When they die, the particles fall to the seafloor and accumulate producing over long periods of time deposits like chalk and chert. 1

Transitional Environments

Shorelines lie between the continental and marine environments. Beaches, tidal-flats, spits, bars, barrier islands, lagoons, estuaries, and deltas all form in the transitional environment. Sand and gravel are dominant beach deposits. Muds occur in tidal flat and estuary environments, often covered with sheets of water for part of the day and exposed to air as the tides rise and fall. Near the shore the waves and currents distribute the sand creating depositional features such as spits, bars, and barrier islands. Deltas are among the most significant transitional environment deposits. They occur when rivers meet the sea and slow down abruptly causing them to drop their sediment load. 1

**Interpreting a rock’s depositional environment**

You can interpret a rock’s depositional environment by looking at a few different features within it. These are listed and explained below.

1. The **color** of the sedimentary rock indicates whether that rock was formed on land or in water. A red or brown sedimentary rock formed by deposition on land. Any iron in the sediment was exposed to air and was oxidized, turning the sediment, and therefore the rock, red. A gray sedimentary rock formed by deposition in water (e.g. an ocean or a lake) where the sediment is not exposed to air, and iron in the sediment cannot be oxidized. This relationship is primarily used in clastic sedimentary rocks because chemical sedimentary rocks rarely contain iron. If you think about their composition, limestones are CaCO3, rock salt is NaCl, gypsum is CaSO4.2H2O, etc.
2. The **size** of the grains which compose the rock and the degree to which those grains are **sorted** are indicative of the type of current which deposited the sediment. The nature of the individual grains is also used primarily in the analysis of clastic sedimentary rocks because they are made up of detrital particles (grains).

Some sediments get deposited very close to home, and others are transported miles. Some are where they are because of a single, short term “event” while others have been reworked and reworked and reworked. Size, sorting and composition can give clues about both the source and the circumstances of a deposit. A few general guidelines to keep in mind are:

* Maximum sizes of sediments moved by glaciers are bigger than those moved by water, which tend to be bigger than those moved by wind.
* Large clasts are more prone to breakage than small ones as they get tumbled around, and so large clasts are often a sign that the deposit is not far from its source.
* If you have ever watched water moving in a river over the course of even a few weeks you have probably noticed that water is not moving the sediment at the same rate all of the time. The spring rains cause flooding that in turn moves some pretty large (coarse) chunks compared to the average midsummer (dry season) transport. The same is true of the wind. The wind can move a house in the course of a tornado, but most of the time only moves fine grained sediments.
* The longer quartz has been buffeted by the waves or wind, the rounder it gets. Water is somewhat viscous, which cushions the grains, and slows the velocity of the particles, and so rounding can take a long, long time.
* Wind blown deposits bang into the ground or each other and get rounded faster.
1. **Sedimentary** **structures** are recognizable patterns or textures formed in the sediment by the external environment. These structures are then preserved when the sediment is lithified. There are many different sedimentary structures, and they can indicate paleoenvironment in many different ways. These include cross-beds, mudcracks, ripplemarks, rain drop impressions, among other things.
* Mudcracks – indicate an environment where the sediment is alternately wet and dry. Environments such as tidal flats, shallow lakes, desert basins, flood plains would be places where mudcracks may occur.
* Ripplemarks – are small waves on the sediment surface made by moving air or water. Current ripplemarks are asymmetrical, with one side steeper than the other. The steeper side is in the downcurrent direction. Oscillation ripplemarks are symmetrical and are formed by the back and forth movement of surface waves in a shallow nearshore environment.
* Crossbeds – grains are transported by wind or water and deposited in ridges, mounds, or heaps in the forms of ripples. Grains collect on the down-current slope, which can have an angle of up to 30 to 35. The direction of crossbeds gives the direction of the current. The steep slopes point in the direction of the current. Crossbeds indicate environments such as sand dunes, river deltas, and stream channels.

Some examples of sedimentary structures can be found in both types of sedimentary rocks, but are primarily found in clastic sedimentary rocks.

1. **Fossils** found in rocks indicate the depositional environment if you make the assumption that the plant or animal fossilized in the rock lived in the same environment in which the rock was formed.

Fossils can be remains of relatively recent organisms, which have not been altered much, if at all. These would include things like teeth, bones, and shells.

Some fossils are petrified where the small internal pores and cavities of the original material are filled with precipitated minerals.

Or the organic matter can be replaced by mineral matter. Much of the details of the organic structure can be retained.

Molds and casts are also considered to be fossils. When the organic structure, such as a shell, is buried in sediment and then dissolved by underground water, a mold is created. The mold reveals the shape of the organism, but doesn’t preserve the detailed internal structure. If these hollow spaces are then filled by minerals, a cast is created.

Carbonization is when fine sediment surrounds an organism. As time goes on, pressure squeezes out the liquid and gaseous components and leaves behind a thin residue of carbon. This is a good way for leaves to be preserved.

Fossils are found in both types of sedimentary rocks but are more common in chemical sedimentary rocks, especially limestone.

References:

1. Tarbuck, E.J.; Lutgens, F.K. 2002. Earth An Introduction to Physical Geology. Prentice-Hall, New Jersey, p. 179.
2. Tarbuck, E.J.; Lutgens, F.K. 2002. Earth An Introduction to Physical Geology. Prentice-Hall, New Jersey, p. 499.
3. http://science.jrank.org/pages/6051/Sedimentary-Environment-Continental-shelf-environments.html">Sedimentary Environment - Continental Shelf Environments

**EXERCISES**

In lab today you will go beyond identifying sedimentary rocks and begin identifying features within the rocks that help you to determine what sedimentary environments they formed in.

1. Look at the display samples of sedimentary rocks with different *environmental indicators* on the table at the back of the room. Work your way through these samples in any order, and fill in the table below.

|  |  |
| --- | --- |
| **WHAT DO YOU SEE?** | **ENVIRONMENT INDICATED** |
| **Color:**1.2.3.4.5. | 1.2.3.4.5. |
| **Grain Size:**1.2.3.4. | 1. 2.3.4. |
| **Sorting:**1.2.3. | 1.2.3. |
| **Sedimentary Structures:**SS1.SS2.SS3.SS4. | 1.2.3.4. |

2. There are several copies of a profile running from the terrestrial environment offshore to the deep marine environment drawn on large paper out on the lab tables. The profile shows the various environments that occur in this idealized profile.

There are boxes of fossils (single-letter label), boxes of rock(s) (double-letter label) and boxes of sedimentary structures (from exercise above) for you to identify and then place in the correct environment. You have a smaller version of this profile in your lab handouts.

a. Identify the rocks in each rock box. Some will have more than one rock type. Fill in the rock table below.

b. Identify the fossils in each box and fill out the fossil table below.

c. Check your rock, fossil and sedimentary structures identifications against the keys.

d. Use the small version of the profile in your packet to record your data. Write the name of each the rocks, any fossils present, and any sedimentary structures you could find that correspond with each depositional environment on your cross-section. The vertical dashed lines divide the environments.

The fossils and sedimentary structures may occur in multiple environments. Use the *Critters* chart and the *Sedimentary Environments* chart to figure out which fossils and sedimentary structures belong with which environment(s).

e. Use your completed cross-section and charts to answer the following questions.

*NOTE: You will be identifying fossils based on their appearance. Use the fossil identification booklets and packets that are on the tables to compare what you see to the fossil descriptions/names.*

3. Which environments in this profile are continental (or terrestrial)?, Marine? Transitional?

4. How do the rocks of the inner shelf and the outer shelf vary? What explains the difference?

5. What do you think is the source for the rocks found in the deep marine environment?

6. The rocks found in the estuary/tidal flat, floodplain and even swamp environments can be very similar. From what you have learned in lab today, what other pieces of data would you use to determine the actual depositional environment of such a rock?

7. Do you think every coastline looks the same as this profile we’ve put together today? If not, indicate 2 things that might be different in a different part of the world.

|  |  |
| --- | --- |
| **Rock Box Letter Set** | **Rock IDs** |
| AA |  |
| BB |  |
| CC |  |
| DD |  |
| EE |  |
| FF |  |
| GG |  |
| HH |  |

|  |  |
| --- | --- |
| **Fossil Box Letter** | **Fossil IDs** |
| A |  |
| B |  |
| D |  |
| E |  |
| F |  |
| G |  |
| H |  |
| J |  |
| K |  |
| L |  |
| N |  |
| W |  |
| X |  |
| Y |  |
| Z |  |
| **Sedimentary Structure**  |  **Sedimentary Structure ID** |
| SS-1 | Use answer from above exercise. |
| SS-2 | Use answer from above exercise. |
| SS-3 | Use answer from above exercise. |
| SS-4 | Use answer from above exercise. |

# LAB B—Geologic Time: Interpreting Sedimentary Sequences of Rock

During today’s lab you will look at three stratigraphic sequences of rock from the southwestern United States--one from the Grand Canyon, Arizona, one from Bryce Canyon, Utah, and one from Zion National Park, Utah. You will correlate these sequences and interpret a geologic history for the region based on the rocks and fossils that you find in these sequences. To do this, you will need to identify various types of rocks and fossils and determine the age ranges for the fossils. From these data you will be able to interpret an environment of deposition and age range for each of the rock units and use this information to construct a geologic history, which you will submit as a graded homework assignment.

**EXERCISES**

1. You will complete all 3 stratigraphic sequences. Notice that in photographs of useful clues. The rock is meant to represent the lithology of each layer, and you should pretend that the accompanying fossils and each layer of a sequence there is at least one rock and a box of fossils and that some contain sedimentary structures as well as any sedimentary structures are found within the rock.
2. Work your way through the strata, identifying the rock(s), the fossils, and any sedimentary structures, or other clues that you find in each layer.
	1. To complete your rock identifications, use the rock and mineral identification guides that we have been using this semester. There may be a few examples of minerals that will prove VERY useful in determining your rock formation. Write your identifications onto the worksheet that corresponds with your stratigraphic sequence under the ‘*lithology’* heading.
	2. To identify the fossils in each layer, use the fossil description packets that we used in last week’s lab. Write your identifications onto the same worksheet under the ‘*fossils’* heading. PLEASE **DO NOT** PUT ACID ON ANY OF THE FOSSIL SPECIMENS.
	3. Note any sedimentary structures or other features shown, and list these in the worksheet that corresponds with your stratigraphic sequence under the ‘*other features’* heading.
3. Using the *Rock Formations in Grand Canyon, Bryce Canyon, and Zion* description sheet, assign a formation name to each of the layers in your sequences.
4. Using all of the data that you have just collected—your rock identifications, your fossil identifications and descriptions of any other features, along with the sedimentary environments chart and the information about depositional environments from last lab—determine a depositional environment for each layer in your stratigraphic sequence.
5. Use the time range charts and the fossils that you have identified for each layer to assign an age range to each of the layers in the 3 sequences.
6. Once the entire class has reached this point, we will pool our information and discuss any discrepancies. Then, correlate these sequences into a stratigraphic column. Once you have all the data, put together a geologic history for the area encompassed by the three sequences. Do this work on your own. It is a graded homework assignment.

**GRAND CANYON STRATIGRAPHIC SEQUENCE**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Lithology | Fossils | Other Features | Formation | Depositionalenvironment | Age |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

**BRYCE CANYON STRATIGRAPHIC SEQUENCE**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Lithology | Fossils | Other Features | Formation | Depositional environment | Age |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

**ZION STRATIGRAPHIC SEQUENCE**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Lithology | Fossils | Other Features | Formation | Depositional environment | Ages |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

**ROCK FORMATIONS IN GRAND CANYON, BRYCE CANYON, AND ZION**

**Rock Formation** – a distinctive series of strata that originated through the same geologic processes. A mappable rock unit that has definite boundaries and certain obvious characteristics.

**Carmel** **Formation**
**Lithology:** Limestone
**Fossils Present:** Brachiopods, gastropods, bryozoans

**Chinle Formation**
**Lithology:** Shales, terrestrial sandstones. Chinle forms part of the “Vermillion Cliffs.”
**Fossils Present:** Petrified wood

**Coconino Sandstone**
**Lithology:** Fine-grained sandstone with massive crossbedding.
**Fossils** **Present**: trace fossils-Vertebrate tracks

**Grand Canyon Supergroup**
**Lithology:** Beds of sedimentary rocks, including sandstones, shales, lava flows, limestones.
**Fossils:** Algae

**Grey Cliffs Group**
**Lithology:** sandstone to shale, both iron rich.
**Fossils Present:** Mudcracks, raindrops

**Hermit Formation / Supai Group**
**Lithology:** Hermit is shale, silty sandstones, sandy mudstones with kaolinite, and sandstone.
**Fossils Present:** Few fossils, but trace fossils in the form of burrows are present.

**Kaibab Formation**
**Lithology:**  Limestones with chert nodules. The rocks grades into dolomites and sandy dolostones to the east,
**Fossils** **Present:** Brachiopods, some Molluscs (gastropods, pelecypods), trilobites.

**Kayenta / Moenave Formation**
**Lithology:** These formations form part of the “White Cliffs.” They are mudstone, siltstone, sandstone.
**Fossils Present:** Dinosaur tracks in the lower part.

**Navajo Formation**
**Lithology:** This too, is part of the “White Cliffs.” Sandstone withlarge-scale crossbeds.
**Fossils Present:** None

**Redwall Limestone Lithology:** Limestone with lots of fossils
**Fossils Present:**  Blastoids, brachiopods, trilobites

**Temple Butte Formation**
**Lithology:** Limestone
**Fossils Present:** No fossils

**Tonto Group**
**Lithology:** Three distinct rock types: sandstone, shale and limestone
**Fossils Present:** Brachiopods and trilobites

**Toroweap Formation
Lithology:**  Largely limestones and dolomites with some sandstones. The mineral *gypsum* is abundant near the top.
**Fossils Present:** none

**Vishnu Schist / Zoroaster Granite**
**Lithology:** Schist and granite
**Fossils:** None

**Wasatch Formation**
**Lithology:** This formation forms the “Pink Cliffs.” The “pink is a result of the ferrous limestone and sandstone.
**Fossils Present:** Mammals!