# Lesson Six: Weathering and Sedimentary Rocks

**Background Reading: Sedimentary Processes**

The formation of sedimentary rocks is the result of several processes. The fundamental processes are weathering of pre-existing rocks, transport of sediment, deposition of sediment, and finally cementation and other processes that occur after deposition (this is called diagenesis). This progression is shown below.

Weathering
Transport
Deposition
Cementation / Diagenesis

## Weathering

The process begins with weathering. Weathering consists of both mechanical weathering (or sometimes called physical weathering) and chemical weathering. Mechanical weathering breaks rocks down into pieces that then provide more surface for chemicals to attack. Thus, mechanical weathering speeds up the weathering processes by providing more surfaces for the chemical to attack.

## Mechanical Weathering

Examples of mechanical weathering are provided in Worksheet 6.1on page 54.

## Chemical Weathering

Oxidation – reaction with oxygen – rust (hematite, limonite)
Solution – dissolving of minerals and release of ions; example: salt (halite) dissolving in water
Hydrolysis– chemical reactions that produce clay minerals

Chemical weathering is aided by the presence of Carbonic acid in rainwater and groundwater.
$CO_2$ in atmosphere and soil dissolves in water to form carbonic acid:
Carbonic acid will dissolve calcite ($CaCO_3$) to release calcium into solution. It can also aid in weathering feldspars and other minerals.
Many minerals weather to clay and release ions: For example, Potassium Feldspar reacts with Carbonic Acid to produce Kaolinite clay, potassium, and silica

Quartz is very stable and does not easily weather due to chemical (or mechanical) processes.

**Transport:**
Mechanisms of sediment transport include Rivers, Wind, Glaciers, Gravity,Waves
Weathering continues during transport. Other important processes also occur during transport. These processes include:

Rounding – This is related to length and mechanism of transport
Transport by rives, waves, and wind cause rounding. There is less rounding with short transport and with glacier transport.
Angularity and sphericity are described in the textbook. These are similar in concept to the idea of evaluating grains by how they have been smoothed and eroded during transport. However, we will keep things simple and only consider rounding in our discussion of how grains mechanically change during transport.

Sorting- is the degree to which grains are similar in size
Sorting is related to length of transport. Longer transport generally results in better sorting. ***In general, the size of grains deposited is related to the energy of transport***. This is a key concept and something we will use in evaluating depositional environment (described below). Therefore, large grains are the only grains that will be deposited in rapidly moving water, and small grains are deposited in slow moving water after all of the larger moving grains have already been deposited (upstream in faster moving water). Small grains are deposited in areas such as bays, lakes, or the open ocean, where the transport energy is low.
Wind and river transport is often an effective method of sorting. Glacial transport is often a poor means of sorting (the exception being the stream transport at the end of a glacier).

**Deposition:** deposition occurs when transport stops.
Depositional Environments are described as: The geographic setting where sediment accumulates.
We will consider three main types of depositional environments:

1. Terrestrial (Nonmarine). This is sometimes called continental,
2. Marine,
3. Transitional (shoreline)

These types can then be subdivided by considering the energy of the setting: low, medium, high energy and specific conditions (rivers, dunes, glaciers)

Example of a depositional environment: A mountain steam is a medium to high energy terrestrial depositional environment.
In general, rivers represent several depositional environments depending on the energy of each environment within the river. For example, we would expect larger grains to be deposited in the high-energy channel environment and small grains (silt or clay) to be deposited in the low-energy environment of the river banks or floodplain.

**Post-depositional changes**: **Diagenesis**
Diagenesis is a collective term for all of the chemical, physical and biological changes that take place after deposition
**Lithification:** an important diagenetic process that includes compaction and cementation to form a hardened sedimentary rock. The cementing agents produced include: quartz, calcite, hematite (iron oxides)
**Oxidation:** oxidation of iron-bearing minerals in the rock give a common red/orange color.

## Sedimentary Rocks

Sedimentary rocks are formed in two general ways. **Clastic sedimentary rocks** are formed when sediments are deposited, compacted, and cemented. **Chemical and biochemical sedimentary rocks** are formed when minerals precipitate from water, or when minerals precipitated by an organism are cemented together.

Clastic sedimentary rocks are characterized by the size, shape, and (for coarse-grained rocks) the composition of the clasts. The clasts sizes are divided into the following categories:

| | |
|---|---|
| Gravel to Boulder size: | >2mm |
| Sand Size: | 0.0625mm-2mm (you can see most sand sized grains) |
| Silt Size: | 0.004mm-0.0625mm (grains cannot easily be seen, but feels "gritty") |
| Clay Size: | <0.004mm (feels smooth and powdery) |

**Clastic Sedimentary Rock Names**

**Conglomerate** is made mostly of rounded gravel- to boulder-sized clasts. (most of the grains are larger than sand size)
**Breccia** is made mostly of angular gravel- to boulder-sized clasts. (most of the grains are larger than sand size)

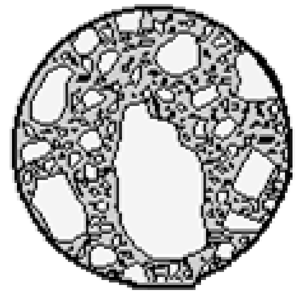
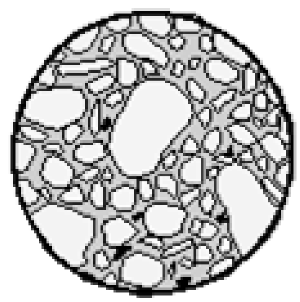
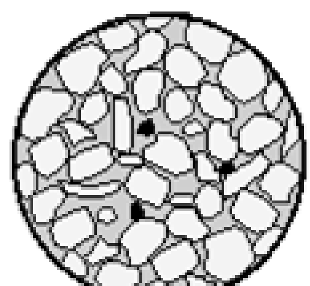
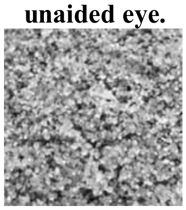
**Sandstones** are made mostly of sand-sized clasts. These rocks are classified based on the composition of grains and the amount and type of material between the grains. They are also described in terms of rounding and sorting of grains.

- **Quartz-Rich Sandstone** (or Arenite) is made of almost all quartz grains with a quartz cement.
- **Wacke Sandstone** (or Graywacke) has a variety of grain types and mud between grains. This is a common sandstone in Humboldt County. You can think of this as a "dirty" sandstone.
- **Arkose Sandstone** contains abundant feldspar. These rocks are common near exposed granite.
- Note: (We will not be using Lithic Sandstone, which is described in the textbook).

**Siltstone** and **Claystone** are formed from cemented silt or clay clasts.
**Mudstone** is composed of both clay and silt.
**Shale** is either Siltstones or Mudstone with distinctive, thin layers or partings.

**Chemical and Biochemical rocks** are characterized by specific minerals.
Common minerals in Chemical Sedimentary Rocks: Halite, Gypsum, Calcite, and Silica (quartz) can precipitate from water.

**Crystalline Limestone** is formed by precipitation of calcite from water.
**Fossiliferous Limestone** is formed from the accumulation of calcite-rich organic fragments (shells).
**Muddy Limestone (Micrite**) looks similar to mudstone, but the mudstone is calcite rich
**Chalk** – powdery calcite-rich rock formed from the accumulation of microscopic calcite forming organisms – this one reacts to hydrochloric acid.
**Clastic Limestone** is a clastic rock (formed of grains), but the grains are calcite rich
**Chert is** formed either out of solution (from silica rich water), or from accumulation of organic fragments (very small silica-rich shells).
**Diatomite** – powdery silica-rich rock formed from the accumulation of one-celled diatoms.
**Evaporites:** Salt (halite) and Gypsum deposits are formed as water evaporates.

<table>
<tr><th colspan="3">Textural Features of Sedimentary Rocks</th></tr>
<tr><th>Grain Sizes</th><th>Grain Shapes</th><th>Grain Arrangements</th></tr>
<tr><td>Gravel Size and Larger<br>greater than 2 mm<br></td>
<td rowspan="4"><br>Angular Grains<br><br>Rounded Grains<br><br>Well-Rounded Grains</td>
<td rowspan="4"><br>Very Poorly Sorted<br><br>Moderately Sorted<br><br>Very Well Sorted</td></tr>
<tr><td>Sand Sizes<br>Ranges from Very-Coarse to Very-Fine Grained Sand<br>2mm to 1/16 mm<br>Grains can be seen with the unaided eye.<br></td></tr>
<tr><td>Silt Sizes<br>1/16mm to 1/250mm<br>(.0625 - .004mm)<br><br>Grains not visible, but feel “gritty”<br></td></tr>
<tr><td>Clay Sizes<br>Less than 1/256mm,<br>(<0.004mm)<br><br>Grains not visible, feels smooth. Grains cannot be seen with a common microscope</td></tr>
</table>

Images: Bazard, 2012 and Public Domain

# Sedimentary Rock Classification Chart

| ***Clastic Sedimentary Rocks*** | | ***Chemical / Biochemical Sedimentary Rocks*** | |
|---|---|---|---|
| ***Grain Size*** | | ***Calcite-Rich Rocks*** | ***Silica-Rich Rocks*** |
| **>2mm**<br>**(granule to boulders)** | **Breccia (angular grains)**<br><br>**Conglomerate (rounded grains)** | **Crystalline Limestone**<br><br>**Fossil-Rich Limestone**<br><br>**Mud-Rich Limestone (Micrite)**<br><br>**Chalk (powdery limestone)** | **Chert (includes flint, jasper, chalcedony, agate)**<br><br>**Diatomite (powdery, silica-rich, from diatoms)** |
| **2mm-1/16mm**<br>**(very-coarse to very-fine grained sand)** | **Sandstones:**<br>**Quartz-Rich Sandstone (Arenite)**<br>**Feldspar-Rich Sandstone (Arkose)**<br>**Mud-Rich Sandstone (Graywacke)** | | |
| **Less than 1/16mm**<br>**(includes silt and clay)**<br>• **Grains not seen**<br>• **Rocks range from gritty (silt content) to smooth (clay rich)** | **Mudstone (massive)**<br><br>**Shale (finely layered silt and clay)** | ***Rocks Made of Evaporite Minerals***<br>**Halite – Rock Salt**<br>**Rock Gypsum** | |

**<u>Worksheet 6.1: Sediment</u>**

***Weathering*** is the breakdown of rocks at the surface of the earth.
<u>Mechanical (or physical) weathering</u> results as force or pressure is applied to a rock resulting in fracture into smaller rock fragments that retain their chemical composition.
<u>Chemical weathering</u> results from chemical reactions that break down the minerals within the rock at a molecular level.

1. Characterized each of the weathering processes in the list below as either mechanical or chemical by writing an M or a C next to the process
    a. A rust colored band appears along an existing crack in a rock.
    b. Exfoliation (pressure release fracturing)
    c. Frost wedging
    d. Tree root wedging
    e. Lichen growth (a moss-like organism that lives on the surface of rocks)
    f. Putting HCl on a calcite sample in lab
    g. The deterioration of the gargoyles on the Notre Dame
    h. Abrasion (sediment is rubbed against a rock)
    i. Gravel in soil breaks down into clay
    j. Salt wedging (in coastal areas salt crystals grow in cracks in rocks, expanding and breaking the rocks)

2. Consider the chemical weathering of granite. Use the table below to identify the minerals that will remain <u>after</u> complete weathering.

**Products of Weathering**

| **Mineral** | **Residual Products (minerals)** | **Material in Solution (Ions)** |
|---|---|---|
| Quartz | Quartz Grains (Quartz does not chemically weather easily) | Silica |
| Feldspars (K, Na, Ca) | Clay Minerals | Silica, K, Na, Ca |
| Micas (Biotite, Muscovite) | Clay Minerals<br>Iron-Oxide Minerals | Silica, K, Mg |
| Amphibole | Clay Minerals,<br>Iron-Oxide Minerals | Silica, Ca, Mg |
| Olivine and Pyroxne | Clay Minerals,<br>Iron-Oxide Minerals | Silica, Mg |

3. For each of the following characteristics, identify whether the characteristic generally increases or decreases with transport time. (Write I or D next to the characteristic)
   a. Grain size
   b. Grain sorting
   c. Grain rounding
   d. Percent Feldspar
   e. Percent Quartz

4. Organize the list of depositional environments based on the energy of the depositional environment:

   Sandy ocean beach
   Windblown desert
   Lake bottom
   Glacier
   Flooding mountain stream
   River floodplain

| Energy | Depositional Environment | Maximum Grain Size |
|---|---|---|
| High Energy<br>↓<br>Low Energy | | |

5. Complete the Maximum Grain Size column in the table above with grain size terms such as “boulder” or “fine sand”

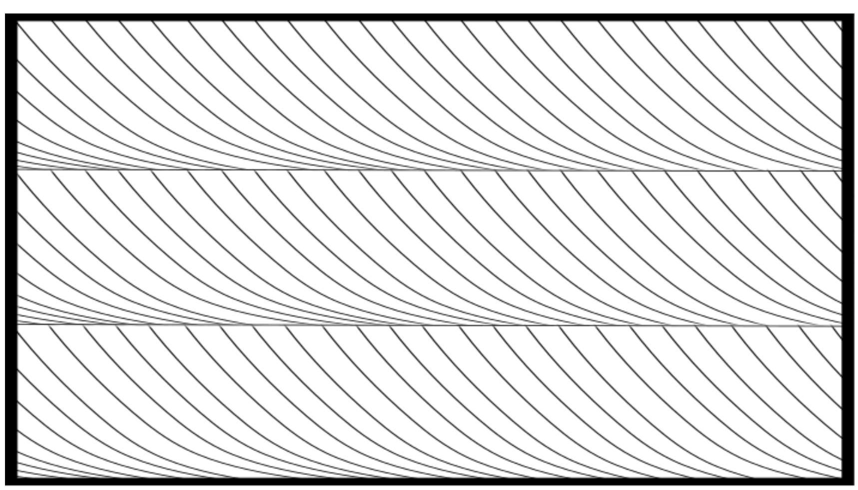
6. Below is a list of descriptions of sedimentary rock units and a list of specific depositional environments. Match the correct depositional environment with the rock that most likely formed in that environment. (Note: There may be one trick question in this)

**Rock 1:** Poorly sorted, angular, arkosic conglomerate. Contains many granite rock fragments. Pink to dark red in color.
**Rock 2:** Well sorted, well rounded, medium grained quartz sandstone. Tan to gray in color.
**Rock 3:** Well sorted, well rounded, fine grained quartz sandstone. Pink to red in color.
**Rock 4:** Fine grained limestone containing abundant marine fossils.
**Rock 5:** Mudstone and shale with layers of evaporite minerals such as halite and gypsum.

***Depositional Environments:***
**Continental Shelf:** The ocean, well past the tidal zone, but still within the continental crust.
**Desert Dunes:** Very large dunes, some up to 100 meters high. Similar to the Sahara.
**Alluvial Fan:** A fan shaped deposit of sediment at the base of a mountain range, where mountain streams flow into flat valleys. These are common in Death Valley.
**Ocean Beach:** You know, a beach.
**Playa Lake:** A shallow lake in a desert valley that sometimes dries completely.

| Rock | Depositional Environment |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |

7. The sketch below shows a cross section view of cross bedding. Label the bedding and the cross bedding and add an arrow showing the direction of current flow.



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**Lab 6.2: Analyzing Sediment**

**Exercise #1:** Analyze the sediment sample(s) provided and describe the rounding and sorting of the sample

**Exercise #2:** Make a grain size card.
Use the Sieve to separate the sediment into different grain sizes.
Glue a small portion of each grain size onto a single card and label the sizes (use terms such as larger than sand, coarse sand, fine sand, etc.)

**Exercise #3:** Decomposed Rock Sample
Clastic sedimentary rocks may include fragments of pre-existing rocks.

A. List the minerals you can identify in these rock fragments?

B. What was the pre-existing rock?

C. Are there any products of chemical weathering present? If so what are they?

**Exercise #4** Sandstones
For each of the sandstones describe:
Graing Size Range: The smallest grain size and the largest grain size present (e.g. silt to granule)
Median Grain Size: estimate that average grain size (what size are most of the grains)
Grain Sorting and Grain Rounding
Grain Composition: In particular is there quartz, feldspar or mud (silt and clay) present
Cement: If possible identify the mineral that composes the cement
Rock Name (e.g. Arkose)

| | **Grain Size Range** | **Median grain size** | **Grain Sorting** | **Grain Rounding** | **Grain composition** | **Cement** | **Rock Name** |
|---|---|---|---|---|---|---|---|
| **A** | | | | | | | |
| **B** | | | | | | | |
| **C** | | | | | | | |

**Lab 6.3: Sedimentary Knowns**
Use the labeled samples provided to answer these questions
Look at the specimens and answer the questions below.

Rock Set 1:
How can one distinguish Breccia from Conglomerate?

Rock Set 2:
How can one distinguish Sandstone from Mudstone (or shale)?

Rock Set 3:
How can one distinguish Fossiliferous Limestone from Crystalline Limestone?

Rock Set 4:
How can one distinguish Micrite (muddy limestone) from Chert?

How can one distinguish Micrite from Mudstone?

How can one distinguish Mudstone from Shale?

Rock Set 5:
How can one distinguish a Quartz-Rich Sandstone from Graywacke Sandstone?

How can one distinguish an Arkose Sandstone from a Quartz-rich Sandstone?

Rock Set 6:
How does Diatomite differ from Chalk?

**Lab 6.4: Sedimentary Unknowns:**

**** These properties may not apply to all specimens and in some cases they may be left blank.***

| | Clastic or Chem/BioChem? | Grain Size (for Clastic)* | Grain Rounding and Sorting (for Clastic)* | Grain composition (for Clastic)* | Cement (clastic) or Mineral (chem) Composition | Acid Test | Fossils | Name |
|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | |
| B | | | | | | | | |
| C | | | | | | | | |
| D | | | | | | | | |
| E | | | | | | | | |
| F | | | | | | | | |
| G | | | | | | | | |

| | Clastic or Chem/BioChem? | Grain Size (for Clastic)* | Grain Rounding and Sorting (for Clastic)* | Grain composition (for Clastic)* | Cement (clastic) or Mineral (chem) Composition | Acid Test | Fossils | Name |
|---|---|---|---|---|---|---|---|---|
| H | | | | | | | | |
| I | | | | | | | | |
| J | | | | | | | | |
| K | | | | | | | | |
| L | | | | | | | | |
| M | | | | | | | | |
| N | | | | | | | | |
| O | | | | | | | | |