Geo 302D: Age of Dinosaurs

LAB 1: Introduction to Rocks and Sedimentary Processes

We would not be able to address the interesting questions of dinosaurs and their place in the history of life without the occurrence of their fossil remains, and the interpretation of fossils depends on their occurrence within their geologic setting. We would be ignorant of the very existence of dinosaurs without preservation of their fossil bones and traces within certain rock types within the earth, and could not begin to interpret their great age, evolution, and living environments without other types of rock, and preservation by different geologic processes. Indeed, all paleontologists are intimately dependent on understanding geology to understand their fossils, and knowledge of rock types is fundamental to paleontological work. Interestingly, biologic processes can contribute to forming certain geologic features or rocks that would not otherwise have been possible.

This lab introduces you to the three major types of rocks, and focuses on the type in which you would expect to find most fossils – sedimentary rocks. Additionally, igneous, metamorphic, and sedimentary rocks allow us to place an age on fossils – either in absolute years (igneous and metamorphic rock types) or relative time (through the deposition of sedimentary layers lying one on top of the other). You should come away from this lab with an understanding of the major rock types and the processes that form them.

All rocks are composed of minerals. Minerals are naturally occurring, solid, inorganic substances with specific chemical compositions. Some common examples are: quartz, calcite, feldspar, and mica, just to name a few. Different rock types contain certain types of mineral combinations in certain particle or crystalline form. As mentioned above, there are three major categories of rocks.

I. Rock Types

1. Igneous rocks. These are formed by crystallization directly from molten material. This molten material is called magma when it is below the surface and lava once it reaches the surface. As the molten material cools, atoms within it begin to combine with one another, forming mineral crystals. As cooling continues, the crystals butt up against one another, eventually interlock, and form a rock made up of many mineral crystals. Igneous rocks can be categorized by their composition, crystal size, and texture. Very few fossils are found in igneous rocks, with the exception of rock composed of volcanic ash which can cool and preserve fossils just as it preserved the former residents of Pompeii.

2. Sedimentary rocks. These are formed in one of two ways. One way is from the erosion, subsequent deposition, and lithification of pre-existing rocks. Sedimentary rocks formed by this process are called “clastic” sedimentary rocks. They are composed of grains ranging in size from very coarse-grained cobbles and pebbles to extremely fine-grained clay particles. Common clastic sedimentary rocks are sandstone, mudstone, breccia, conglomerate, and siltstone. The other way to form sedimentary rocks is by precipitation of minerals from water. This may be accomplished by evaporation (often yielding halite [=rock salt]) or through the action of organisms in the water (limestone). We will study sedimentary rocks and the processes associated with them more closely in this lab.

3. Metamorphic rocks. Under conditions of intense heat and pressure, pre-existing rock can be physically and chemically altered, transforming (“metamorphosing”) into an entirely new type of rock. These are called metamorphic rocks. They have not been re-melted, but the conditions get harsh enough to break down the bonds of many of the minerals making up the rock. When heat and pressure finally subside, entirely new minerals are often behind, such as garnet. Common metamorphic rocks include gneiss (from all of the other rock types), marble (from limestone), schist (from muddy sediments), and slate (from shale). Fossils are less commonly found in metamorphic rocks and those are usually distorted.
II. The Rock Cycle

An interesting feature about these three rock types is that any one of them can undergo processes that turn them into either of the others, or new versions of the same type. This inter-relationship is called the **rock cycle**, first proposed by James Hutton almost 200 years ago. For example, suppose a particle of quartz forms deep in the earth as part of a large underground mass of igneous granite. Over millions of years, the Earth’s crust is uplifted, the overlying rock erodes away, and our little quartz crystal is exposed to the air. A pounding rainstorm knocks the quartz particle off the granite, it rolls down a small stream, and is buried with millions of other rock fragments. After years of burial, dissolved minerals carried in groundwater cement the rock fragments together. Our quartz crystal is now part of a sedimentary rock. Later, the sedimentary rock containing the quartz crystal is shoved deep under the earth’s surface by movements within the earth’s crust. As the rock is shoved deeper, heat and pressure increase greatly. Eventually the particles within it are physically and chemically changed, resulting in a metamorphic rock. The quartz crystal/particle may contribute its chemical composition to the formation of completely new minerals. If the metamorphic rock continues to be heated, it may melt entirely so that the atoms making up our one-time quartz crystal are released to reform another igneous mineral. This is just one example of the many different combinations and inter-relationships found in the rock cycle.

![Diagram of the rock cycle](image)

**Figure 1.** Many different combinations of geologic processes contribute to the rock cycle and result in different rocks types.
III. Sedimentary rock types

Sedimentary rocks have special importance to the field of paleontology because they are the only rock type that regularly preserves the remains of organisms. By the time you finish this lab, you should be able to identify basic sedimentary rock types and their environments of deposition.

All sedimentary rocks are originally deposited in horizontal layers, or beds. You can usually see the lines of contact (bedding planes) distinguishing different beds. However, sedimentary rocks are formed in several ways. **Evaporites** are formed by the evaporation of water. As the water disappears, the minerals in solution begin to precipitate out and form layers on the bottom. Rock salt and gypsum are relatively common evaporites. **Carbonates** include all limestones and dolomites and are generally formed in warm water environments. They are called carbonates because they contain carbonate ions (CO$_3$). Limestones are made of calcium carbonate (CaCO$_3$: calcite) and are usually biogenic. This means they were created through the activities of organisms. Many life forms, particularly marine organisms, secrete calcium carbonate in the form of shells or skeletons. Their remains build up large layers of carbonate sediment, which eventually lithifies (turns to rock) into limestone. Dolomites are similar to limestones in having carbonate ions, but they have some of their calcium replaced by magnesium. They are rarer, and often form as evaporites, or as altered limestones. Nearly all of the bedrock in the Austin area is some form of carbonate.

**Clastic** sedimentary rocks are formed by the erosion, transport, deposition, and lithification of pre-existing rocks. They are categorized on the basis of their grain size and to the degree of grain roundness. A grain is a particle or a larger clast (fragment) from an original source rock. For example very large, well-rounded grains (e.g. cobbles, pebbles) cemented together make a conglomerate. Very large, angular clasts cemented together form a breccia. Other clastic rocks defined in order of their grain size are: sandstone, siltstone, and mudstone. Shale is formed from a very fine mud that is highly fissile, meaning it splits very easily along its thin bedding planes.

IV. Clastic Sedimentary Depositional Environments

The higher the relative energy of a transport method (e.g. ice, water, wind), the larger the grain size of the material that it can transport. For instance, water flowing quickly in mountainous flash flood can carry larger pieces of material than water moving in a pond. It simply takes more energy to transport large particles than it does to transport smaller ones. High energy environments usually have a relatively steep gradient (change in elevation over a distance). The steeper the slope, the more force will be generated as the material moves downhill due to gravity. In addition to transporting coarser sediment, higher energy environments also build larger sedimentary structures. Sedimentary structures include bedforms such as ripples, dunes, sand waves, and bars.
Figure 2. The mean gradient (i.e. slope) of water flow determines the water’s flow energy and the size of grains it can carry before they drop out and settle to the bottom of the water.

The degree of rounding of a grain can tell you how far a particular clast has traveled from its parent rock. The more rounded the grain, the further it has traveled. A jagged, sharp-edged clast probably has not traveled far from its source. Sorting and size can also give some idea about how far clasts have traveled from their parent rock. If you have a poorly sorted mixture of various sized sediments, it probably has not traveled far from the parent rock, whereas well sorted, fine grained sediments have probably traveled further away from their parent rock.

The steepness of a slope in terrestrial (above sea level) environments can influence whether an organism’s remains have a good or poor chance of preservation. Mountain goats are far less likely to be preserved in the fossil record than a fish that died in a pond.

Because most commonly preserved terrestrial sediments were deposited in river systems, we often find dinosaur remains in fluvial deposits. The term “fluvial” refers to rivers and streams. There are a couple basic stream types you need to recognize.

**Braided streams** are relatively high energy systems. They are usually wide, shallow, fast-moving streams with a large percentage of coarse-grained sediment in their beds. Between the rather straight-sided banks of the stream channel are numerous coarse grained sand and gravel bars, and gravelly islands. This gives the stream its “braided” appearance. The figure below shows a braided stream in aerial view.
Figure 3. Example of a braided stream system.

Figure 4. Braided streams carry and deposit a variety of clast sizes, depending on how steep the slope of the stream, and how much water flows through it at any time.

**Meandering streams** are moderate to low energy streams with sinuous channels. Because of their sinuosity, the velocity of water is different in different parts of the channel. Along the inner banks of a bend in the stream water slows down, loses energy and deposits sediment and any other suspended material, building large sandy bars called **point bars**. The water along the outer bank of a bend moves relatively faster, possesses more energy, and is an area of erosion where previously deposited layers of rock are uncovered. This bank is called the **cutbank**. Outside the banks of the actual channel, meandering streams often have large floodplains. As the name implies, during floods these areas are covered with sluggish water filled with fine grained sediment. They are sites of episodic deposition of fine grained sediments such as silts and muds. The figures below show a meandering stream in aerial view.
Figure 5. Example of a meandering stream. Note the abandoned loops (“oxbows”) of the stream.

Figure 6. Labeled meanders in a stream showing the (sand) point bars and cutbanks. Erosion of the cutbanks would destroy fossil deposits, while point bars are often good deposits for finding terrestrial fossils.

Lakes leave behind **lacustrine** deposits. The relatively still, low energy waters of most lakes allow the deposition of the finest grained sediments, such as fine silt, mud and clay. **Deltas** form wherever running water meets standing water, such as a lake or an ocean. When running water in a channel suddenly slows down and spreads out upon meeting standing water, it loses energy. Because the water no longer has the energy to transport its sediment, the material falls out and forms a large, fan-shaped pile of sediment that grows out into the body of water. Over years, a deep wedge of deltaic sediment can form. Lacustrine and deltaic deposits can
be very rich sources for both plant and animal fossils, as their low energy environments do not rapidly destroy organic remains before they may be buried.

Figure 7. Example of a delta deposit at the meeting of a river and a lake.

Figure 8. Deltas deposit their sediments further and further into the body of water as a wedge of sediment.
Exercises

1. Quickly draw a map-view sketch of the creek seen on the powerpoint slide, from the edge of the bridge downstream to just around the bend. Label all cutbanks, point bars, and areas with the potential for sediment deposition:

2. Based upon the shape of the stream and its channel, what category of stream system is this?

3. If Nutter the squirrel were to die and fall into the creek today, where is the most likely place for Nutter to be buried and hopefully preserved to one day become a fossil? Why?

4. If you’re walking along the banks of the creek today, where is the best place to look for a fossil from much older rocks? Why?
5. Given that Nutter would have washed into the site from upstream, in what type of condition would you expect to find him? Would you expect to see soft tissues preserved? What about the shape of his bones?

6. Given the nature of the rock cycle, what is the likelihood that Nutter would survive for 100 million years in a sedimentary rock?

7. Identify these three rocks and briefly describe how each of these formed.
   a) 
   b) 
   c) 

8. Which of the rocks from question 5 is most likely to contain a fossil?

9. a) Compare sediments in jars A through C. Which of these was deposited further from its source rock (e.g. the rock that supplied the clasts within it)? Why do you say so?

   b) Again, compare sediments in jars A through C. Which clasts were deposited in a higher energy environment? Why do you say so?