GY 112L Earth History

Lab 5

Fossil Preservation

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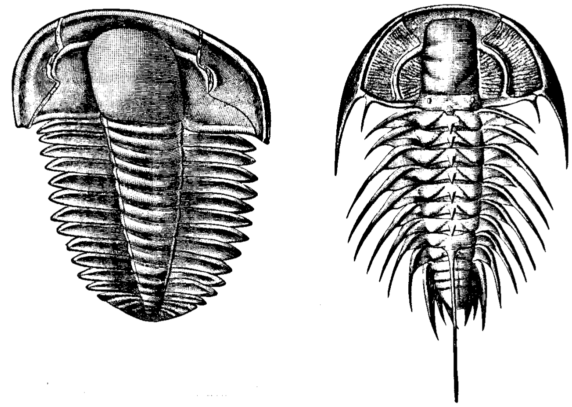
This manual is constantly being updated and occasionally, even improved. Typos, grammatical errors and sections that make no sense whatsoever may, or may not, be intentional. If you find an error, show it to your instructor. You may get bonus points. More likely you will be told to go away

The recipes that are included in some sections are intended to prove that you can eat anything as long as you serve it with plenty of ketchup. Neither Haywick, nor the Connors are responsible for any food poisoning that might occur if you actually try them.

http:/www.southalabama.edu/geology/haywick



Lab Five

Introduction to Fossils and Modes of Fossil Preservation

Background: For the rest of the semester, you will get up-front and personal with various **fossils** from the **geologic** or **rock record.** The study of fossils is called **paleontology**. Most people (and that includes GY 112/112L students), have a rudimentary understanding of fossils and paleontology, but there are also a lot of misconceptions that need to be corrected. You will eventually come to appreciate that animals evolved at different geological times, and a lot of the juxtapositioning that we envision is incorrect. For example, primates are recent additions on this planet. Consequently, there is no way that humans (e.g., Fred Flintstone) could have lived with the dinosaurs. Hollywood commonly confuses geological time and the evolution of life. The 2000 animated Disney film *Dinosaur* featured cute fuzzy lemurs attempting to save an orphaned baby dinosaur 65 million years ago. Unfortunately, there was a time gap of many 10s of millions of years between the death of the dinosaurs and the evolution of those primates.

Another misconception is the difference between paleontology (*the study of fossils*) and **archaeology** (*the study of the remains of man*). **Paleoanthropologists** study fossil man but they do not study dinosaurs. If an archeologist happened to find the skull of a *Tyrannosaurus rex* in a site that was supposed to contain hominid remains, then he or she either dug too deep, or read the map incorrectly.

Earth's biological history can be revealed through studying the evidence of past life. Indeed as you have seen in class, the fossil record greatly contributes to theories in other components of Geology as well as to Biology. Paleontology is a subdiscipline of Geology that studies ancient forms of life, their interactions as well as evolution. Paleontology can be broken down into many specific areas including **paleobotany** (*the study of fossil plants*), **micropaleontology** (*the study of microscopic fossils, something that Dr. Murlene Clark specializes in*), **invertebrate** and **vertebrate paleontology** (*the studies of, respectively, fossils without, and with, backbones*).

Figure shows two species of trilobite, just one of many thousands of beasties that have come and gone in the geological record. From Le Conte, J., 1905. Elements of Geology. D. Appleton & Co. New York, 667p.

The term *fossil* refers to anything that is recognized as direct evidence of, or an indication of, pre-existing life. Fossils include both the remains of animals and plants (**Body fossils**), and the traces of those organisms (e.g., burrows, plant roots, feces; **Trace fossils**). It is a sad fact that we have found only a small fraction of all of the beasties that actually lived over the past 600 million years. Most, organisms (90-98%?), left no record of their existence. This is not really all that surprising if you think about it. Consider all of the creatures that today inhabit the Gulf of Mexico. All will eventually die, but few will ever make it to the rock record. Most will be eaten by something else before their remains make it to the sea floor. Even if they make it to the seafloor, something living in the sediment (worms, bacteria) will probably devour them. Sea shells are pretty durable, but taken out of a marine setting, they can quickly dissolve away entirely. The odds of any one fossil being preserved long enough for us to find it are very, very low. However, enough *have* been preserved for us be able to reconstruct most of the Phanerozoic Era. But just remember that the fossil record is anything but complete.

Fossil preservation is rare and depends upon many conditions. To become preserved in the geologic record, an organism must:

- have preservable parts such as bones, shells, teeth, or wood.
- have lived in a suitable environment for fossilization
- have died quickly and been buried soon after death
- not be disturbed after burial
- be protected from contact with oxygen

One other thing should be stated about fossils before we get to the next section. Some of the fossils that you will see in the lab here and in the rocks out "there" are the remains of extinct "beasties". Trilobites died off at the Permian-Triassic boundary 245 million years ago so any rocks you find that contain trilobites must be at least 245 million years old. But not all of the fossils that you will encounter represent extinct groups. Some even have living relatives. For example, there is a mollusc shell (a bivalve) in New Zealand called *Austrovenus stutchburyi* that today only lives in estuaries and very shallow marine environments around that country. Students that went on a USA trip to that country in 2001 found fossils of *Austrovenus stutchburyi* in rocks 500,000 years old on top of a mountain 1000 feet high that was 25 km away from the shoreline. This indicates 2 things: 1) the shell, which is *not* extinct, has been around for at least half a million years (quite a long time for a bivalve) and 2) 500,000 years ago, the top of the mountain had to have been at sea level. Paleontology can provide an enormous amount of important information if you are a careful and accurate observer.

Modes of Preservation: The way in which fossils can be preserved is highly variable. The type of preservation depends largely on the material the beastie was composed of and the fluids that they were exposed to. This section details the most common modes of preservation.

Body Fossil Preservation:

1) Unaltered (**Pristine**) Preservation: Most marine shells are composed of calcium carbonate ($CaCO_3$). There are 2 different minerals that share this general chemical formula that are used by beasties to make their shells, tests and skeletons: **aragonite** and **calcite.** These 2 minerals are **polymorphs**☼**.** That means that they have the *same chemical composition, but different crystal structures* (see Haywick's GY 111 and 112 web lecture notes on fossil

preservation for more details about this☼). Polymorphs usually have different properties, as do aragonite and calcite, but in this case, the differences are not all that great. Aragonite is only just slightly more soluble than calcite in fresh (meteoric) water, However, this is a very IMPORTANT difference as far as fossil preservation is concerned. Aragonite dissolves *first* meaning that few fossils composed of aragonite survive for all that long in the rock record[1]. Most aragonitic fossils that have been exposed for even short periods of time to fresh water lose their pristine appearance and appear "chalky". This is the first indication that the fossils are dissolving. If you identify this in any of your lab specimens, it's best to call this mode of preservation **chalky** or **partially dissolved**.

Aragonite is widely used by modern molluscs (includes clams and snails), corals and lots of other beasties. Calcite, the more stable polymorph of calcium carbonate (at least in meteoric water), is also used by some types of molluscs, but is the mineral of choice for brachiopods, bryozoans, foraminifera, trilobites and some extinct groups of corals. Distinguishing between calcite and aragonite for the fossils you will encounter in GY 112L labs is actually pretty easy. If you are looking at old aragonite, it will be chalky. If you are looking at old calcite, it will not. If you are looking at very old calcite (i.e., Paleozoic aged), it will still look detailed (e.g., you will see the original structure of the shell/skeleton), but it will be dark blue/grey in color. Calcite, like fine wine, darkens with age. Aragonite dissolves with age.

Besides calcite and aragonite, there are several other minerals that organisms build hard body parts out of. For the most part, you will not see these in GY 112L, but here is a bit of information about them if you are interested in biomineralization.

- Calcium phosphate; several varieties of this compound occur as minerals (including apatite). This is the major mineral constituent of vertebrate bones.

- **Opal** ($SiO_2 \cdot H_2O$); is relatively soluble in water (at least compared to quartz or chert) and so it rarely survives unaltered. It is used by some marine microfossils (e.g., diatoms and radiolarians), and is sometimes found in algae and sponges.

- **Chitin**; this is a major component of arthropod exoskeletons - like crabs and insects. It is an organic compound that is similar to cellulose. Chitin is often subject to biotic decay so sometimes all that is left is a carbonized film. Trilobite exoskeletons were made of this and other materials.

- Combinations; many hard parts are made of a combination of mineralogies. For example, trilobites often have exoskeletons made of chitin impregnated with high magnesium calcite. Some bryozoans are composed of aragonite and calcite.

2) **Impressions:** Soft body parts are very rarely preserved in the rock record, but are among the most eagerly sought fossils. Under very special conditions (quiet depositional environments, rapid burial, anaerobic conditions), outlines of worms and leaves might be preserved. These fossil impressions are almost like lithographics (a type of line art) and are almost always found in shale (especially black shale).

3) **Entombment:** This occurs when animals become encased in an agent that cuts them off from potentially destructive processes like oxidation. Soft and hard parts are usually

[1] The oldest skeletal aragonite dates back to only the Jurassic period.

preserved. The most common material involved in entombment is **amber** (fossilized tree sap). Insects are frequently preserved in this manner.

4) **Mineral replacement**: In this type of preservation there is an actual substitution of one mineral for another. The detail of preservation varies from excellent to crappy depending upon the speed and manner of replacement. Almost all types of mineral replacement are induced by pore water within the rocks that contain the fossils. As the water seeps through the rock, it may dissolve some components of the fossil, but simultaneously precipitate another mineral in its place. If the dissolution-precipitation process occurs at a small scale (e.g., one molecule at a time), replacement can be done without losing too much of the original detail. Often this replacement occurs at the cellular level, preserving many microscopic details of the original specimen. If the replacement is less selective, you will get a poorly preserved fossil. You may see many types of replacement. Here are some of the most common varieties:

- Replacement by Calcite (Recrystallization)
- Replacement by Dolomite
- Replacement by Chert (Silicification)
- Replacement by Quart (Silicification)
- Replacement by Pyrite (Pyritization)
- Replacement by Hematite
- Replacement by Limonite

5) **Permineralization:** Many original materials are porous, like bones, wood and shells. These pore spaces can be filled in by other minerals which is called perimineralization. It is NOT mineral replacement as you can't "replace" a hole with a mineral. You must FILL IT IN. Cryptocrystalline quartz (chert) and quartz are common perimineralization minerals. Unaltered bone will look spongy, be soft (hence easily scratched), and be lighter than perimineralized bone which will be heavier with the 'holes' filled in. The same goes for wood materials that when altered will be dense and harder to scratch. Even certain corals and sponges can be permineralized.

6) **Petrifaction:** This is the replacement of organic material AND the filling in of holes by secondary minerals. Petrifaction therefore consists of mineral replacement *and* perimineralization. Chert is the most common pertification substance. Test for it using standard hardness tests.

7) **Carbonization**: In this type of preservation, as decomposition occurred, the specimen lost all of its oxygen, hydrogen, and nitrogen leaving mostly carbon behind. The remains are generally a black or grey film. Plants are often preserved in this manner but graptolites, fish, and arthropods can also be found in this state. Plant material in this form can be referred to as a **carbon impression**.

8) **Concretions**: This mode of preservation involves a fossil found inside a concretion or nodular rock. As the sediment encapsulated the specimen, the minerals cemented to the soft tissues. Commonly calcite, hematite or siderite ($FeCO_3$) is the preserving material. Concretions may part along a plane of weakness that was created by the presence of the fossil (e.g., parallel to a leaf or fish) giving you two sides of the same fossil.

9) **Molds**: This is an impression of the original specimen in the enclosing sediment. The mold can be **external** or **internal**. A mold actually makes an 'opposite' image of fossil. So, where there may be ridges and knobs on the actual specimen, in a mold they will look like

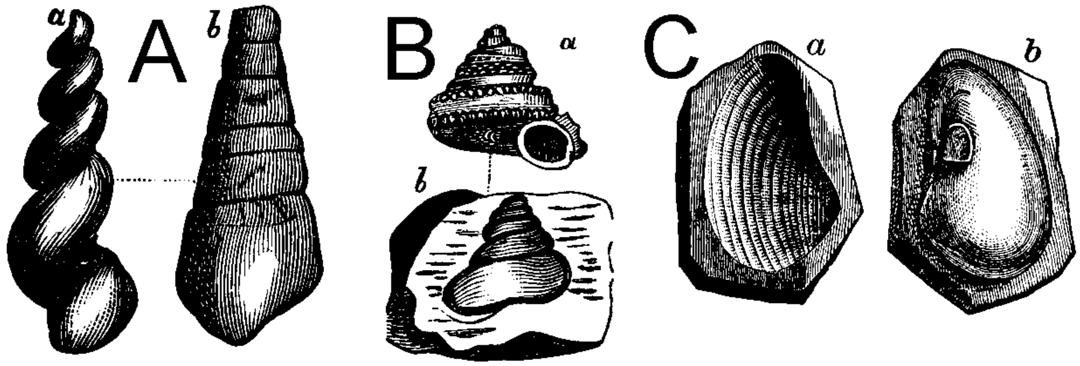


Figure 5-1: *Images of casts and mold. A: A turritelid gastropod; a - the internal mold; b - the external unaltered portion of the test. B: Another gastropod; a the unaltered test; a cast of the test. C: A bivalve shell; a - an external mold of the shell; b - an internal mold of the shell. Figure from Le Conte, J., 1905. Elements of Geology. D. Appleton & Co. New York, 667p.*

indentations and depressions. When you walk on the beach your foot leaves a mold behind. If you pour plaster into the mold you get a cast of the bottom of your foot ….. which leads to…….

10) **<u>Casts</u>:** This type of preservation occurs when minerals or sediment fill the void where the original material once was. The mineral or other material will take its form from the mold, so the cast is a replica of the original, now long gone. For most specimens found prior to the Phanerozoic Eon, soft parts had to leave molds (impressions) in soft sedimentary materials in order to preserve their existence.

Trace Fossils

Trace fossils (also called **ichnofossils**) are the evidence of a plant or animal's activity. Although not "true" fossils (they are not the remains of body parts), trace fossils preserve evidence of organism's activities/behaviors. They include footprints, burrows, horizontal feeding traces, resting marks and even fossilized "turds" (**coprolite**). Ultimately, they record disturbances from activity such as locomotion, feeding, or rooting. They are very useful in the interpretation of paleoenvironments. Given that trace fossils reflect activity, many different organisms doing the same thing can produce similar traces. Likewise, an organism engaged in a different activity can leave more than one trace. These types of remnants in the geologic record are the cause of **bioturbation** which is defined as the disturbance of sediments due to biologic activity.

1) **<u>Burrows</u>**: These trace fossils are usually vertically or sub-vertically orientated and were produced by organisms as they penetrated downward or upward in *unconsolidated* sediment. Most of the time, they were feeding (eating crap left by other organisms). There are numerous types of burrows and a surprising number of them are identifiable and traceable to specific beasties. These recognizable burrows are classified in much the same way as hard fossils and in some cases, are excellent for determining paleoenvironments of deposition. The one I am most familiar with is *Ophiomorpha nodosa* which is a vertical burrow 2 cm in diameter. It is easily recognized by its "nobly" outer wall. The beastie that makes the burrow (a type of shrimp) keeps the burrow open by lining it is sediment glued together with its

feces. Not very appealing, but very diagnostic. The neat thing is that *Ophiomorpha nodosa* only occurs in shallow marine (nearshore environments). If you find it in your rocks, your rocks were formed adjacent to a beach.

2) **Horizontal feeding trace fossils:** These are left by organisms like snails that move across the top of sediment feeding on the organic stuff at the sediment-water interface. Like burrows, these trace fossils are formed in unconsolidated sediment.

3) **Borings**: Boring are holes that are drilled into consolidated or hard materials *long after the sediment has lithified*. You might initially confuse them with burrows, but burrows get filled back in by the very material that the beastie was moving through. Borings remained open (that's how you can tell that the sediment was firm or hard). There are many different boring organisms out there (and this does not include your humble instructors!). Many bivalves and snails bore into hard materials like rock and even wood, largely for protection.

3) Encrustation: This form of trace fossil occurs when an organism glues a tube or even part of its skeleton down onto a hard substrate like rock or even a shell. **Serpulid** worms form a calcite tube in this manner and live in it for protection. The growth of hard skeletons on firm substrates is actually common occurrence. Other organisms that do it are corals, bryozoans and barnacles

4) **Pseudofossils:** Just when you thought you knew it all about fossils comes things that are NOT fossils. **Dendrites** look like small plants branching on the side of rocks but they are actually mineral encrustations such as manganese oxide. **Slickensides** are vertical striations along rock faces that are the result of movement along a fault face.

Glossary of Other Important Fossil and Fossil Preservation Terms and Concepts

Abrasion: Wearing-down of parts due to movement with respect to sediment is an indicator of environmental energy. Significant abrasion is commonly found on skeletal material collected from areas of high energy such as beaches, areas of strong currents or wave action. In some cases, body parts are completely obliterated.

Articulation: Skeletons are usually **disarticulated** or broken up soon after death. Articulated skeletons, therefore, indicate rapid burial or otherwise removal of the skeleton from the effects of energy of the original environment.

Bioerosion: This encompasses many different corrosive processes by organisms. For example common causes of degradation are **boring** and **grazing** (trace fossils on fossils!)

Fragmentation: Breakage of skeletons is usually an indication of high energy resulting from wave action or current energy. Fragmentation also can be caused by other organisms through either predation or scavenging.