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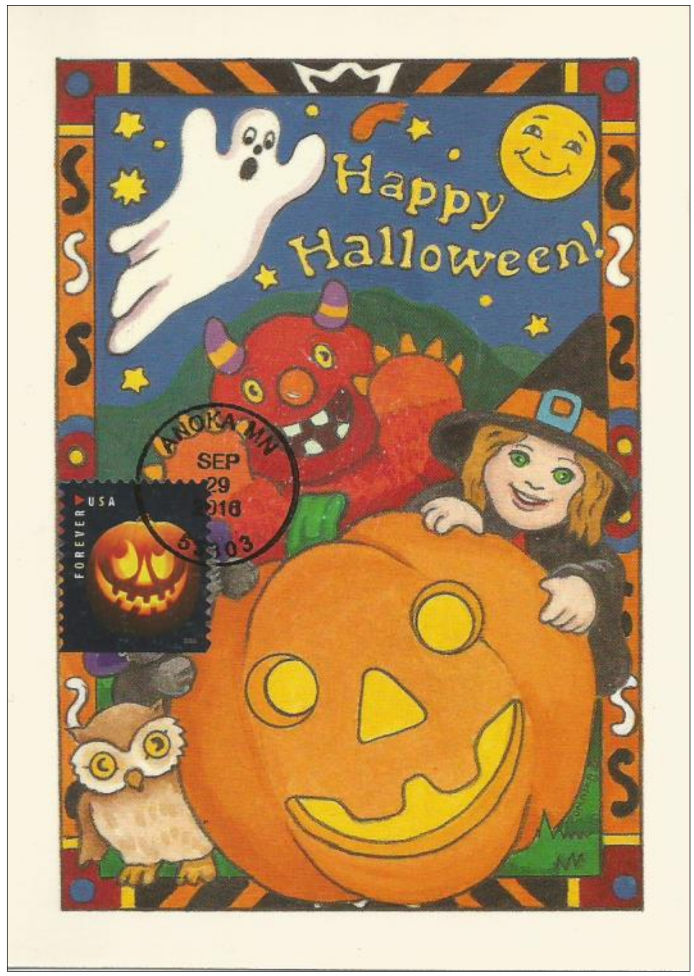


Stamp: Halloween Jack O' Lantern, Scott #5140

Postcard: "A Happy Halloween", original illustration by Anna Pomaska, published by Dover Publications

Postmark: official circle-date first day of issue, Anoka, MN 9/29/1916

How are fossils made? A look at fossilization portrayed on Maximum Cards

By Peter Voice

A **fossil** is the remains or traces of a once living organism preserved in the geologic record. My historical geology professor added to the definition that the organism had to have lived 10,000 or more years ago (I actually teach this as well – it is a bit arbitrary, but provides a working cut-off between paleontological and archaeological research). The remains can include mineralized hard parts of the skeleton (shells, teeth, bones) or soft flesh (tissues, hair, feathers). Traces are an intriguing (and at times very frustrating) part of the definition – as these are geologic structures formed by organisms that exhibit that a.) the animal was present in the environment and b.) it was actively doing some behavior. Trace fossils include footprints, nests, coprolites (fossilized feces), egg shells (Figure 2) and many other structures. They can be frustrating because we cannot be certain that we know what kind of organism produced the structure (and some simple burrows for example are known to be made by multiple species in modern environments). The study of trace fossils is called **ichnology** (Figure 1).

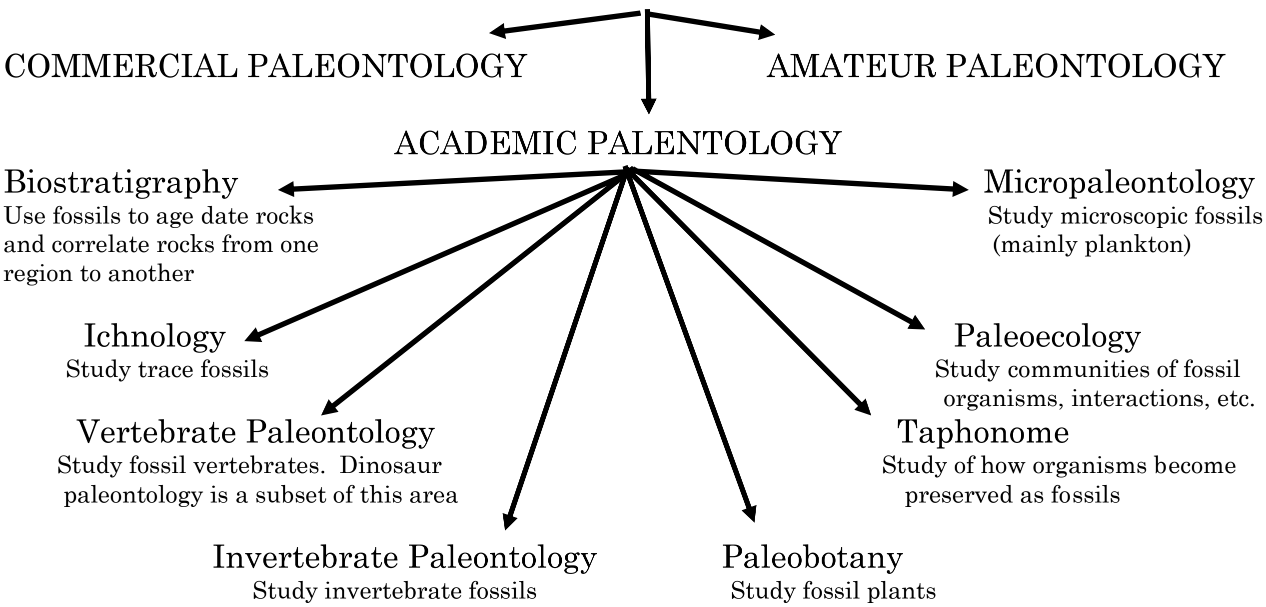


Figure 1: Types of Paleontology with brief descriptions of the various sub-disciplines in Paleontology.

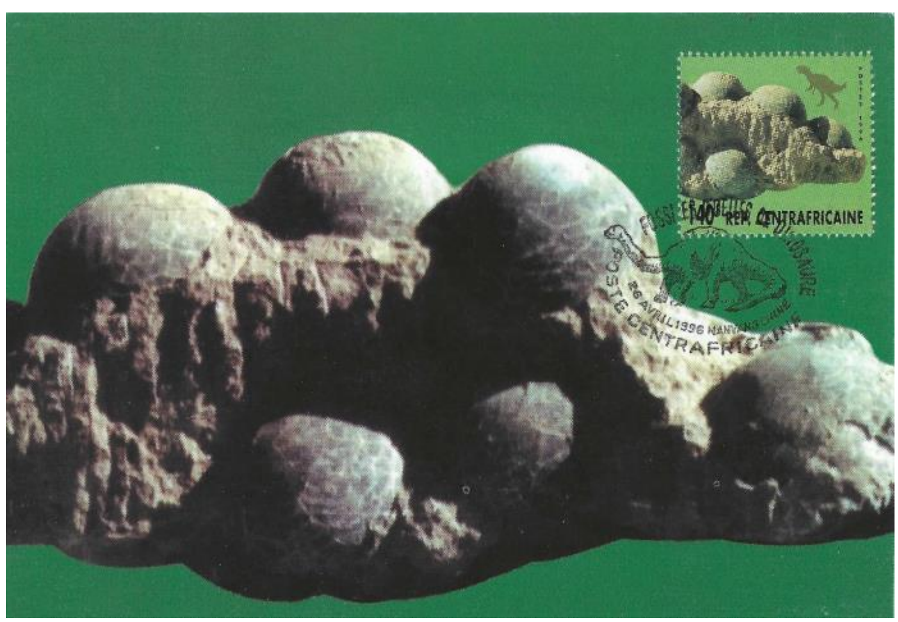


Figure 2: Fossilized dinosaur eggs are an example of a trace fossil. At the time this set was issued, Paleontologists would have had to cut the egg open to see if an embryo is present. Today, Paleontologists use micro-Computer-aided tomography (micro-CT) to image the interior of the egg. Micro-CT uses high energy x-rays at a frequency that is safe for rock. The technology is similar to CT-scans for medical diagnoses – but uses a higher intensity dose of x-rays than would be safe for a person. Central African Republic, Apr. 28, 1996, SC: 1130c.

Taphonomists define several mechanisms that might preserve an organism as a fossil. These mechanisms include unaltered remains, recrystallization, replacement, and carbonization and compression. In addition, one mechanism preserves the shape of the organism but not the actual remains – casts and molds. Each mechanism will briefly be described below with examples of stamps that illustrate the mechanism. In all cases, burial is key to fossilization – as quickly burying an organism will prevent scavenging (and the breakdown of the body into scattered pieces by messy eaters), but also removes the organism from the effects of oxygen and microbially- and fungally-mediated decomposition.

Unaltered remains are rare and are limited to relatively recent rocks. Soft-bodied preservation as unaltered remains are known from highly specialized environments. Probably the best examples come from Pleistocene mammals preserved frozen in the permafrost in northern North America and Siberia. In these cases, cold, dry air mummifies the body followed by burial and can preserve fine details like the stomach contents. A variety of frozen animals including bison, horses, mammoths, caribou and wolves have been found. Other cases of soft-bodied preservation include desiccation and mummification in arid settings or preservation in tar pits such as the La Brea Tar Pits of California. Fossils in amber preserve the shape of the animal, though over time decay will alter the chemistry of the preserved remains. The oldest unaltered skeletal materials include Mother of Pearl shells in ammonoids (a coil-shelled animal related to squids and the *nautilus*) that date back to the Early Jurassic.

How does an organism become a fossil? Paleontologists have spent the better part of two centuries working to figure this out. There is even a sub-branch of paleontology (Figure 1) called **taphonomy** that focuses in part on fossilization. Taphonomic research includes understanding how an animal dies (illness, predation), how the body becomes buried, how the fossil becomes preserved and later is brought to the surface where paleontologists can find it. Some illnesses as well as parasitism can leave traces of symptoms preserved in the bones of the affected animals. Examples include parasitic sores from *trichomonas* in *Tyrannosaurus Rex* jaws and silicosis in the joints of North American Rhinocerids. Some taphonomists study the traces of predation – abrasion on bone or shell from teeth of predators. Some naticid snails for example use their tongue-like radula to bore into the shells of other snails or clams, leaving a distinctive circular boring in the shell. Some fossils even exhibit partial healing with new shell or bone growth partially filling in the predation scar.

Recrystallization is a common process that preserves many mineralized skeletal elements – especially shells. Most marine animals today secrete shells made of up calcium carbonate in the form of aragonite. Aragonite is one of two common polymorphs of calcium carbonate – the other being the mineral calcite. Calcite and aragonite are chemically the same, but the way the calcium and carbonate ions are arranged is different in each mineral. Aragonite is less stable at Earth surface conditions. A clam shell is made up of tiny crystals of aragonite embedded in a framework of collagen and chitin (Figure 3). After burial, as groundwater flows through the porous structure, chemical reactions can slowly reorganize the aragonite into calcite, while also growing the crystals larger to fill in the void left as the collagen and chitin decay. After fossilization, a recrystallized fossil exhibits a chemistry that is very similar to the original skeletal composition (Figure 4).

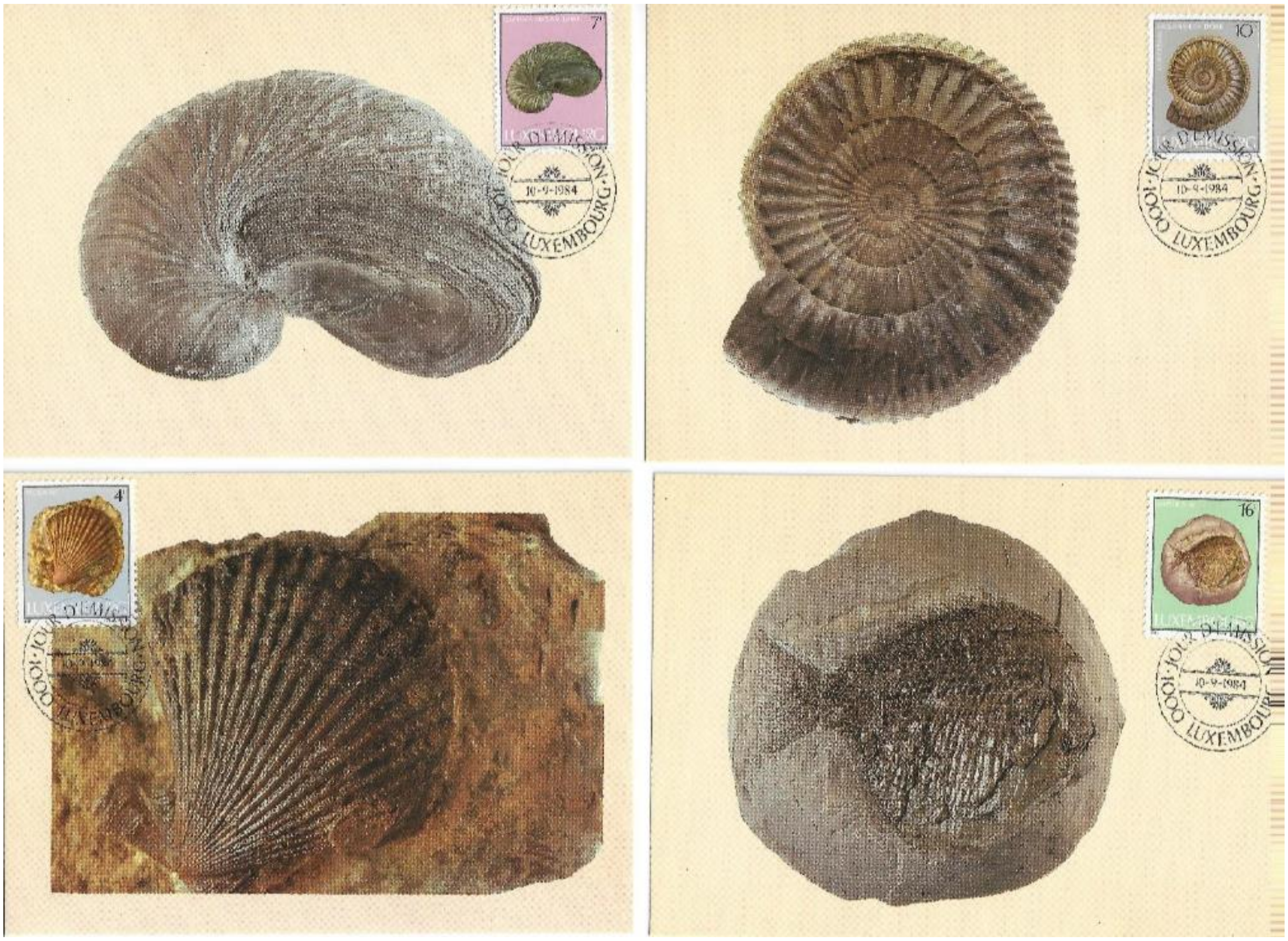
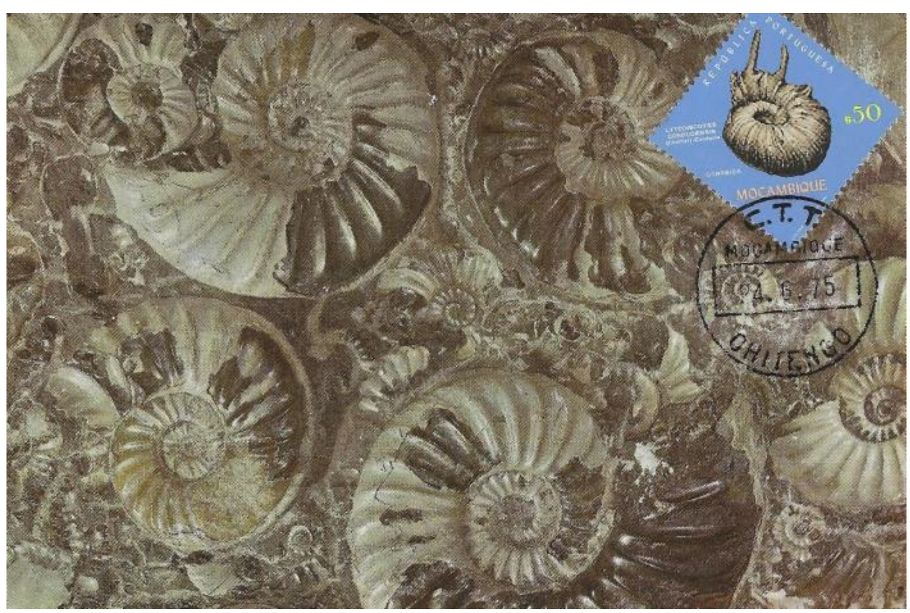


Figure 3, this set of maxi-cards from Luxembourg illustrates recrystallized shell materials from *Gryphea arcuate* (a relative of the modern oyster), an ammonoid, *Coeloceras raquinianum*, and a scallop *Pecten* sp. The fossil fish *Daepidius* sp., likely is partly recrystallized and partly replaced. Luxembourg, October 9, 1984, SC: 714-717.

Figure 4: Partially recrystallized ammonoids on maxi-card – I think the lighter colored material is original unaltered shell material. Mozambique, January 15, 1971, SC: 495 on maxi-card postmarked June 24, 1975.



Replacement generates some of the prettiest fossils that paleontologists have described. As the name suggests, the original hard (or soft parts in the case of wood – see Figure 5 & 6) parts are replaced by new minerals. There are two flavors of replacement: **petrifaction** and **permineralization**. During petrifaction, the organism is quickly dissolved and replaced generating a fossil that shows the coarse features of the original plant or animal. Permineralization is a slower process – operating at the atomic scale by slowly replacing one atom at a time. Because Permineralization is a slow process, permineralized fossils generally exhibit exceptional detail that can include the structure of individual cells in the body! Replacement usually generates a fossil with a completely new chemistry – common replacement minerals include pyrite (FeS2), silica (SiO2) and opal (hydrated SiO2), and apatite (more common in porous bone where this Calcium Phosphate mineral fills the pores left behind after decay of collagen).

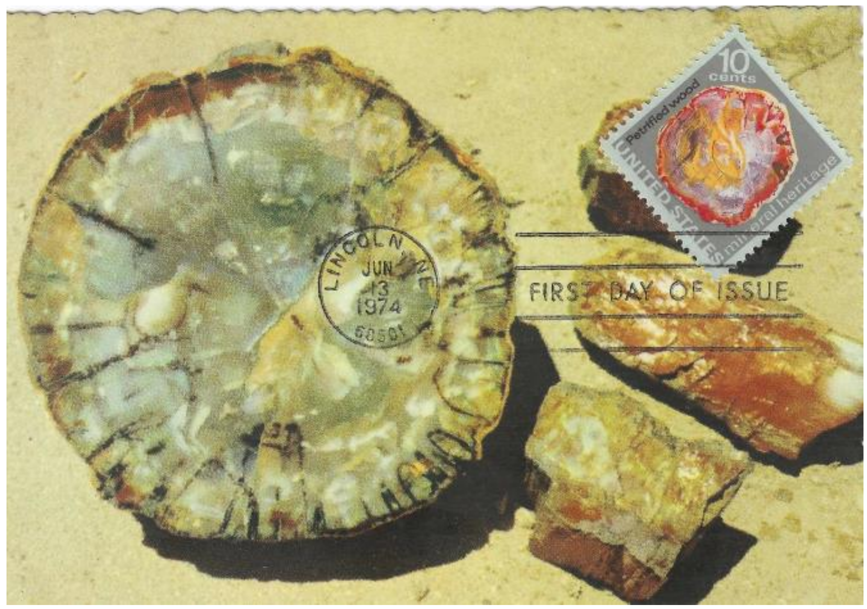


Figure 5 – Without a thin section, it is a little bit difficult to tell whether this silica-replaced wood experienced petrifaction or permineralization. The fossil does exhibit some structure – the growth rings are faint but visible. The outer rim of the fossil represents the bark. The two smaller pieces to the right show less visible structure and are likely petrified. United States of America, June 13, 1974, SC: 1538.

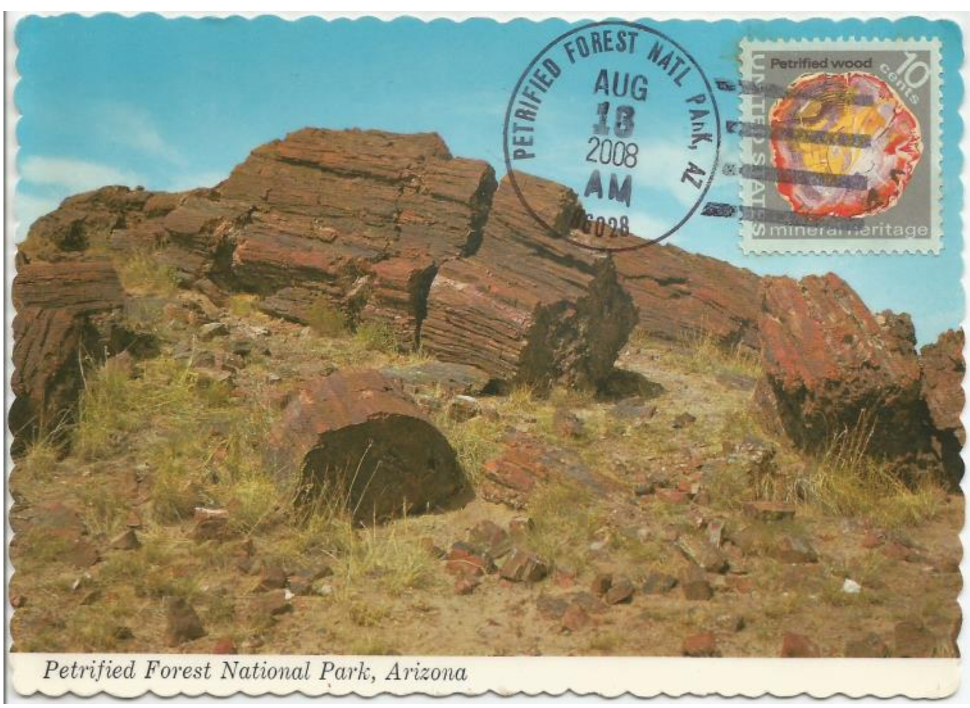


Figure 6 – Another card using SC: 1538. This card shows a field of Petrified wood in the Petrified Forest National Park with a Petrified Forest National Park, AZ postmark. That is dated 8/18/2008.

Carbonization and compression is another mechanism that preserves soft-bodied organisms or the soft-bodied tissues of organisms with mineralized skeletons. After burial, as more and more sediments are laid down on top of the animal, heat and pressure volatilize organic compounds and slowly convert the body to pure carbon (graphite). The fossil tends to be compressed into a 2-d sheet. Organisms like plants and jellyfish are commonly preserved as carbon films. In some cases, carbonization will preserve carbon films around the skeleton of an animal (Figure 6) – showing the shape of the animal with flesh on the bone. Carbon films often form in fine-grained rocks like some limestones and shales – and some taphonomists think that clay minerals may be partly responsible for the preservation of carbon films.

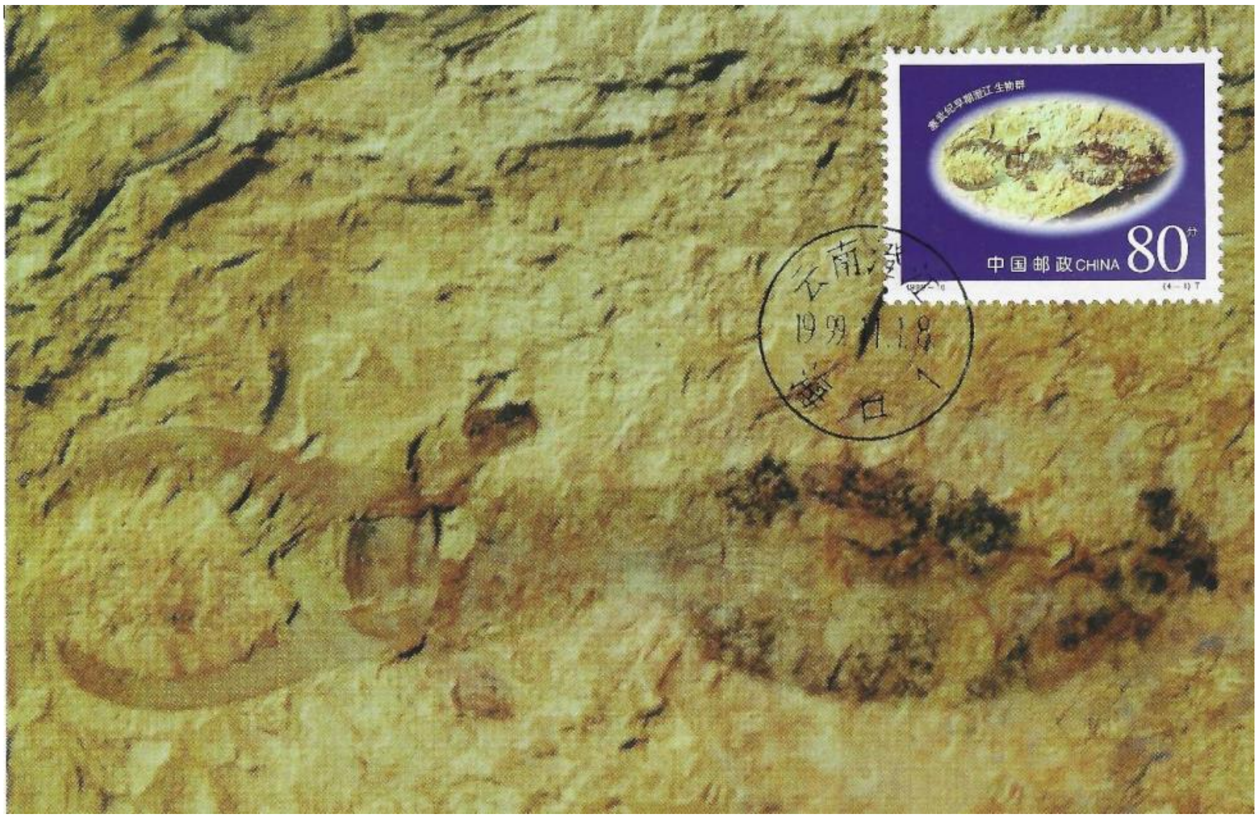


Figure 7: Maxi-card and stamp illustrate a carbon-film of a primitive arthropod from the Chengjiang Fauna. The Chengjiang Fauna are preserved in rocks slightly younger than the Burgess Shale of North America – both sites provide insight into the early evolution of animals from exceptionally preserved fossils. China, November 1, 1999, SC: 2980.

The last mechanism does not preserve the actual animal but instead both an impression of the organism (a **mold**) and a replica of the organism (a **cast**). After death, the animal falls into mud – if you were to come across the body later on, you could pull the animal from the ground and see the impression left behind. Footprints are a similar idea – as you step in mud, the mud conforms to your feet. Then as you take your next step, pulling your foot out of the mud and leaving behind an impression of the sole of your foot. If the animal is completely buried, and groundwater has dissolved the shell and flesh, a void space can be left in the rock. This void space has the shape of the animal that decayed away. Later on sediment can filter down into the void or cement can be precipitated by groundwater to fill the void. In both cases, the material forms a 3-dimensional replica of the animal. Molds and casts are complicated by the observation that some animals can form multiple molds (think of snails – where sediment can conform to the outer surface of the shells as well as fill in the hollow after the snail's body decayed away. This has led to more nomenclature – with internal molds (Figure 8) and external molds (Figure 9). In a clam, the external mold shows the surface ornamentation – ribs, spines etc., while the internal mold exhibits the muscle scars and pallial line (where the flesh of the mantle attaches to the shell).

Figure 8: External cast of an ammonoid showing the surface ornamentation of the shell. The stamp shows an external mold of an ammonoid. Netherlands, April 27, 1962, SC: B364.

Figure 9: This official North Korean maxi-card shows an internal mold of a snail, *Hormotoma*. North Korea, November 10, 2013, SC: 5221.

Unfortunately, fossilization is a rare process. Paleontologists recognize that most organisms have very little chance of making it into the fossil record. Fossilization is more likely for organisms with mineralized skeletons that lived in marine environments where burial was rapid (Figure 10). In terrestrial environments, weathering and erosion may break down the organism before it gets buried (and scavengers and decomposers can also attack the remains). Paleontologists also recognize the fossilization is more likely if the species was very abundant (so future paleontologists exploring our era might find a lot of cow and human remains – due to both abundance and for humans – burial customs).

Figure 10: Arthropods like this lobster make their exoskeleton out of a tough mixture of calcite (calcium carbonate, a mineral) and chitin (a protein). In this case the skeleton is partially compressed – with the dark coloring of the fossil from the original organic matter converting into graphite. Animals like this are preferentially preserved in the fossil record because in marine systems they are relatively quickly buried after death. The calcite portion of the exoskeleton has recrystallized. Libya, November 25, 1996, SC: 1557c.

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