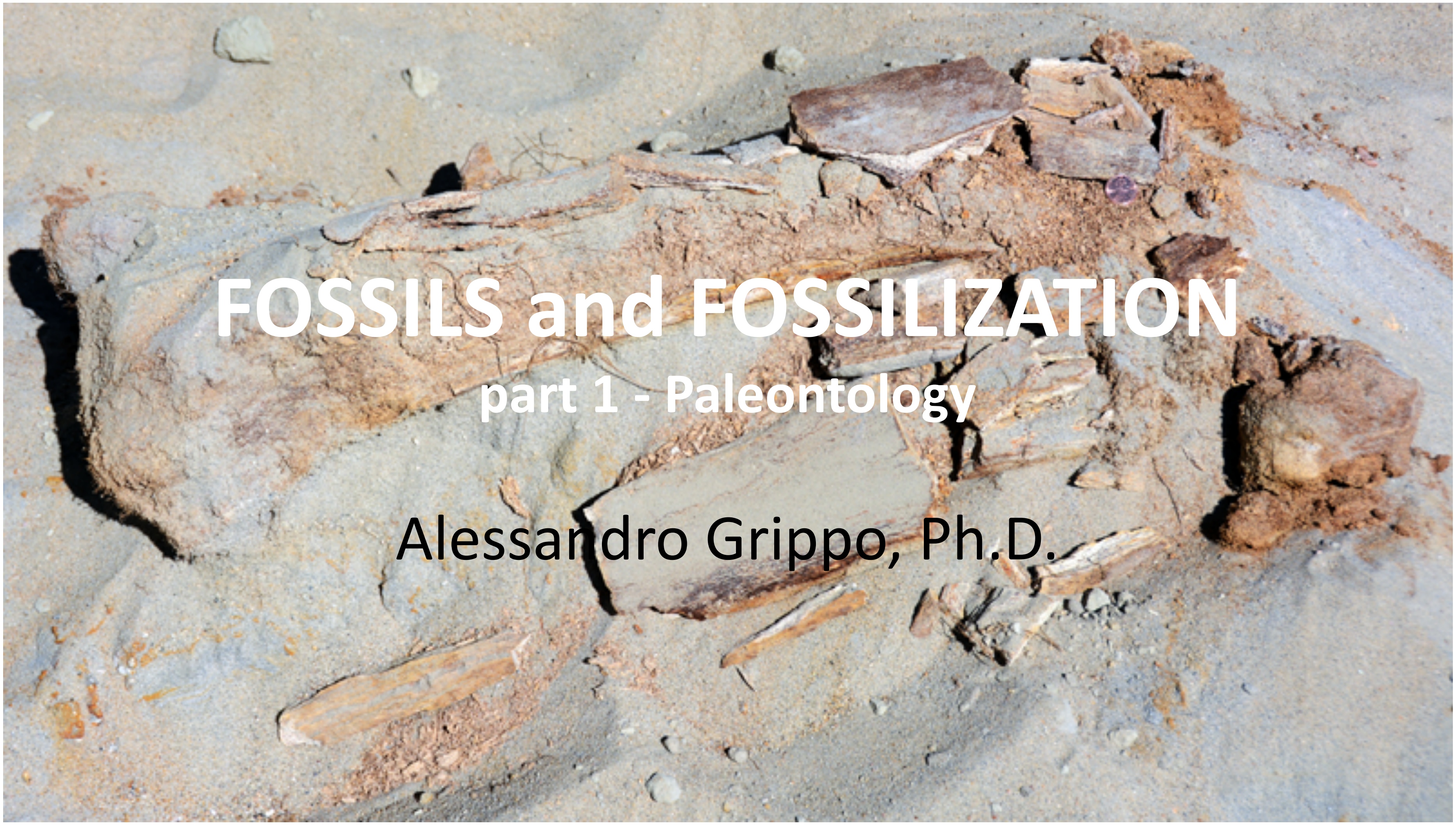

FOSSILS and FOSSILIZATION

part 1 - Paleontology

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Mammoth Bones, from Lone Pine, California

Fossils and Fossilization

- What we know from previous classes:
  - Fossils are the remnant of ancient organisms or of their activity (trace fossils)
  - Fossils indicate an environment of deposition
  - Fossils indicate a relative time (Fossil *Zones*)
  - Fossils are mostly found in sedimentary rocks

Macrofossils vs. Microfossils

- Macrofossils are visible
  - Most fossils in museums are macrofossils
- Microfossils can only be seen with a microscope
  - Microfossils are more common, tend to remain intact, and provide more information than macrofossils

Macrofossils

Tyrannosaurus rex
Royal Tyrrell Museum
Drumheller, Alberta

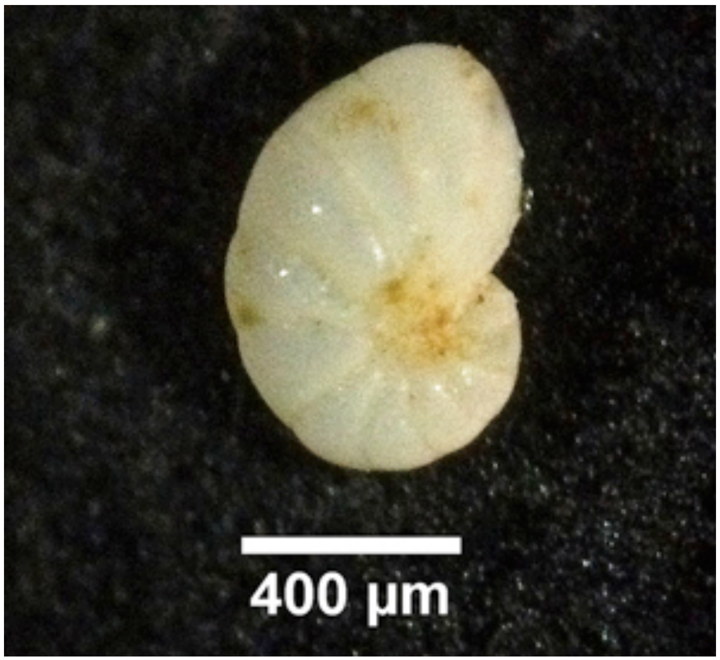
Elephas primigenius
George C. Page Museum, La Brea Tar Pits,
Los Angeles, California

Macrofossils

Turritella
Big Bend National Park
Terlingua, Texas

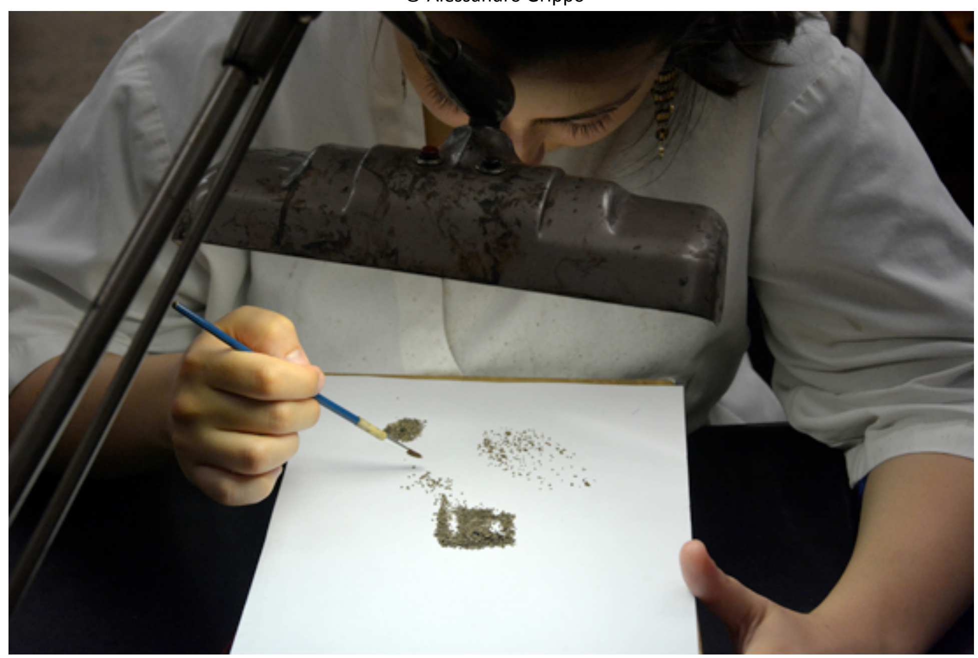
Cycadoidea etrusca
"found in an Etruscan tomb in Marzabotto"
Museum of Geology and Paleontology
Universitá di Bologna, Bologna, Italy

Microfossils



Florilus chesapeakensis, Miocene
Randle Cliff Beach, Maryland
From the blog [Fossils and Other Living Things]

A micropaleontologist at work with microfossils at the George C. Page Museum, La Brea Tar Pits
Los Angeles, California



Preservation of Fossils

- Hard, mineralized parts (bones, shells, teeth, etc.) tend to be preserved more easily than soft parts
- Soft parts are subject to rapid microbial decay in presence of oxygen
- Hard parts can also contain an organic matrix that would hinder durability and preservation of hard parts too

Chances of fossilization

- Can be reduced by:
  - Biological activity
    - scavengers
    - organic tissue decay
    - use of hard substrate by other organisms
  - Physical elements (weathering)
    - wind (abrasion)
    - freeze-thaw cycles on land
    - currents and wave action in the ocean (hydraulic force and abrasion)

What materials are living organisms made of?

- The most important ones are carbonates, phosphates, silicates and a variety of organic compounds
  - *Carbonates* include $CaCO_3$, secreted by a variety of different organisms, as calcite or aragonite. Aragonite is less stable than calcite: over time it will dissolve or turn into calcite (at ~ 300°C)
  - *Phosphates* include calcium phosphate, one form of which is apatite, $Ca_5(PO_4, CO_3)_3(F, OH, Cl)$. Phosphates are important components of the teeth and bones of vertebrates and of a few other organisms.
  - Hydrous *Silica*, or *Opal*, SiO_2*H_2O, is important in sponges, diatoms and radiolarians.
  - *Organic compounds* include:
    - Chitin, a major component of Arthropods' cuticles and Fungi
    - Cellulose and other Polysaccharides, a major components of cell walls in Algae and Plants
    - Lignin, a component of tissues in Vascular Plants
    - Collagen, a dominant component of the connective tissues of animals
    - Keratin, a protein constituent of horns, claws, bills, and feathers

What goes into who (including us!)

This table shows different groups of organisms that are important in Paleontology
and the most important Inorganic and Organic Components they produce

● major component ○ minor component

	Inorganic constituents				Organic constituents				
Group	**Carbonates**	**Phosphates**	**Silica**	**Iron Oxides**	**Chitin**	**Cellulose**	**Lignin**	**Collagen**	**Keratin**
Prokaryotes	●	○		○		○			
Algae	●		○		○	●			
Plants	○		○	○		●	●		
Unicellular eukaryotes	●		●	●	○	○			
Fungi	○	○		○	●	●			
Porifera	●		●	○				●	
Cnidaria	●				○			○	
Bryozoa	●	○			●			○	
Brachiopoda	●	●			●			○	
Mollusca	●	○	○	○	○			○	
Annelida	●	●		○	○			●	
Arthropoda	●	●	○	○	●			○	
Echinodermata	●	○	○					●	
Chordata	○	●		○		○		●	●

Adapted by Alessandro Grippo from:
Towe, K.M., (1987) Fossil Preservation. *In:* R.S. Boardman, A.H. Cheetham, and A.J. Rowell (eds.), *Fossil Invertebrates*.
Palo Alto, California, Blackwell Scientific Publications, pp. 36-41.

Fossils and environments

Primary Habitat of Major Fossil Groups		
Marine		**Terrestrial**
Benthic	Pelagic	
Brachiopods Corals Foraminifera Mollusks Ostracods	Calcareous nannofossils Conodonts Diatoms Dinoflagellates Foraminifera Radiolaria Vertebrates	Mollusks Spores and Pollen Vertebrates (courtesy of the USGS)

How do Fossils get preserved?

1. **Freezing** (preservation in ice)

2. **Preservation in amber** (amber is solidified resin)

3. **Carbonization** (through distillation of organic matter)

   $C_6H_{12}O_6$ (organic matter) —> 6C (carbon) + $6H_2O$ (water)

4. **Permineralization** (ions in solution that replace the organic matrix in skeletal materials)

Clockwise from top left:

1. Freezing: *Oetzi*, human remains from Bolzano, Italy
2. Preservation in amber: a movie prop, with an amber-encased mosquito
3. Carbonization: a dragonfly from the Green River Formation, Wyoming
4. Petrifaction: the trunk of *Araucarioxylon arizonicum*, showing growth rings on transverse section, Arizona

pictures 3 and 4: © Alessandro Grippo

How do Fossils get preserved?

5. **Petrifaction** (total replacement of organic matter with mineral material)

6. **Replacement** (similar to Petrifaction, but replacement was so slow that fine details are preserved)

7. **Recrystallization** (the structure keeps its shape but loses its structure; example, aragonite turning into calcite)

8. **Molds and Casts** (a mold is a negative impression of a fossil outer part; form a mold we can obtain a positive cast)

9. **Trace Fossils** (traces of organisms' activity, such as tracks, burrows, footprints, etc.)

Clockwise from top left

1. Replacement: pyritized trilobite from Beecher's beds, Utica, New York
2. Recrystallization: Triassic ammonite, Lone Pine, California (© Alessandro Grippo)
3. Mold and cast: a brachiopod valve
4. Dinosaur foot trace, Kanab, Utah (© Alessandro Grippo)

Pseudofossils and Artifacts

- Pseudofossils
  - *inorganic structures that look like biological remains*
- Artifacts
  - *features that are generated during the processes that lead to preservation of fossils*

A pseudofossil: crystals of manganese resembling ferns

Manganese dendrites from the Jurassic Solnhofen Limestone from Bavaria, Germany

- Fossils are preserved in sedimentary rocks
- Both fossils and sedimentary rocks reflect a particular environment of deposition

- Using the principle of uniformitarianism, and a knowledge of today's organisms, we can improve our understanding of ancient rocks, environments and geography

Taphonomy

- Still, the information we get from fossils is different (in quantity and quality) from that we would get form a live organism

- By understanding these differences we can better understand the fossil record

- This is the field of **taphonomy**, which includes:
  - Biostratinomy (what happens to an organism before burial)
  - Diagenesis (what happens to an organism after burial)

The Bias of the Fossil Record

What we see in the fossil record is not a faithful record of what was alive at a certain time

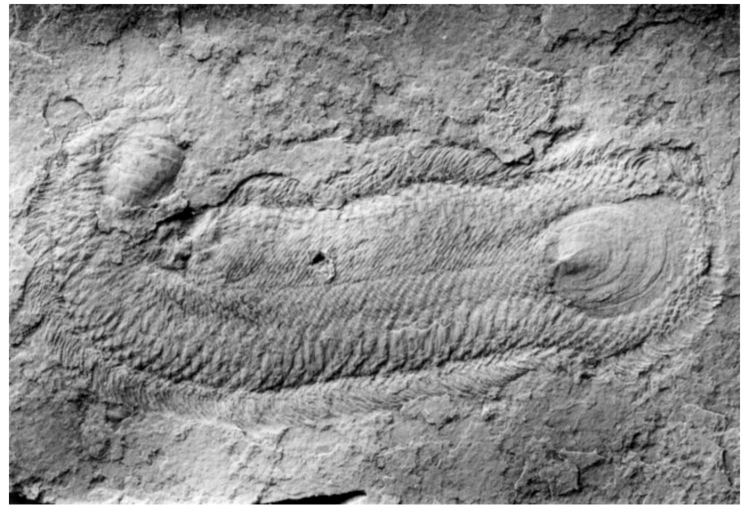
For instance, insects (arthropods) represent today 82% of all animals alive today but less than 1% of the fossil record

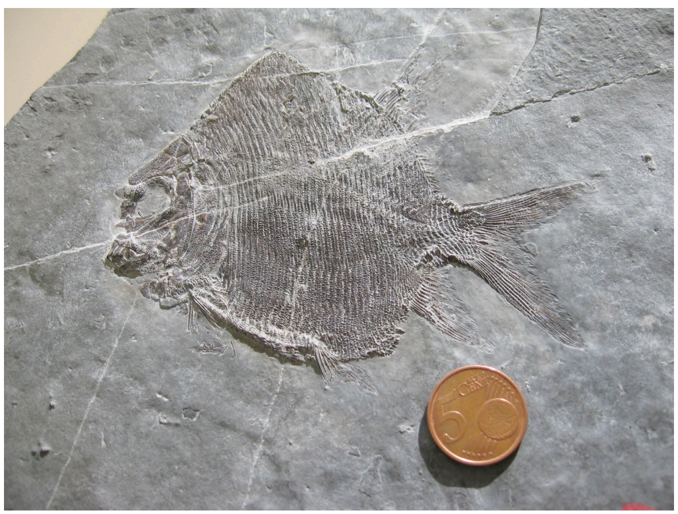
Animal Groups	% of living species today
PROTOZOANS	2.5%
CNIDARIANS	0.8%
BRYOZOANS	< 0.1%
BRACHIOPODS	< 0.1%
VERTEBRATES	3%
PORIFERA	< 0.1%
MOLLUSKS	7.0%
ARTHROPODS	82.0%
ECHINODERMS	< 0.1%
all others	5.0%

Lagerstätten

- Deposits of exceptionally high quality
  - Conservation Lagerstätten
  - Concentration Lagerstätten
  - Most Lagerstätten:
    - rapid burial
    - anoxic conditions
    - quite, low-energy areas
    - little or no diagenesis

examples of **Lagerstätten**





Clockwise from top left:

-Petrified Forest, Holbrook, Arizona, USA
(© Alessandro Grippo)

-Sirius Passet, Greenland, Denmark

(www.palaeontologyonline.com)

-Besano, Varese, Italy

(www.comune.portoceresio.va.it)

How the Fossil Record changed over Time

- Preserved sediment vs. its age
- Fossils present in preserved sediment

- Life evolved over time, so fossils are different because of:
  - Species abundance
  - Skeletal composition
  - Kind and distribution of life forms

How the Fossil Record changed over Time

- Bioturbation
  - Beginning in the Lower Cambrian, then increasing in the Middle-Upper Ordovician, bioturbation marks the evolution and diversification of several different animal groups
- Skeletal Mineralogy
  - The amounts of Calcite vs. Aragonite in organisms' shells are influenced by Plate Tectonics

How the Fossil Record changed over Time

- Geographical and Environmental Distribution of Fossiliferous Rocks
  - Most rocks today, even on land, are marine in origin, so most research is done on sediments that were originally deposited in the ocean

How the Fossil Record changed over time

- Deep marine sediments
  - can be sampled directly from the ocean but subduction destroys deep marine rocks older than 200 my
  - marine rocks older than 200 my are scant on land
- Shallow marine deposits
  - most common: formed on the continental shelf during periods of high sea level, and exposed during low sea level
- Terrestrial deposits
  - less common: subject to erosion. usually we find ancient coastal lowland environments. Overall, terrestrial deposits are not as important as the pothers

Fossils and Fossilization

end of part 1