Introduction to **EARTH HISTORY**

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What is Earth History

- A scientific study of the changes that occurred over 4.6 billion years during which Earth existed in the Universe
  - physical change
  - chemical change
  - biological change
  - astronomical change

Earth History: does it matter to us?

- Desire to know about our world and to understand where we come from
- Necessity to find resources for our society
- Lessons from the past
  - Past changes can help foresee the future

Geology's contribution to human thought

Deep time

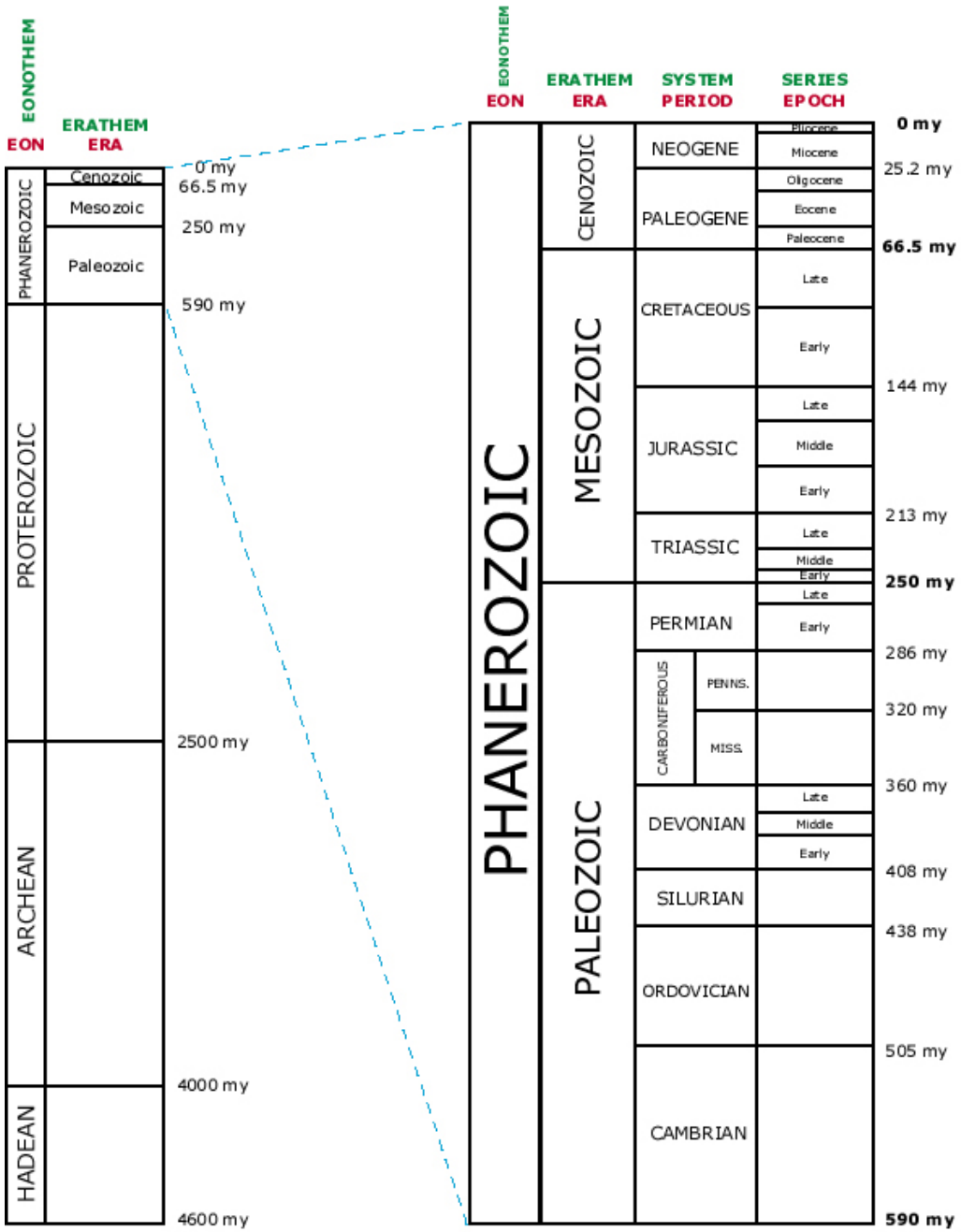
- Geology shows that Earth is 4.6 billion years old
- Humans have been around for an incredibly smaller amount of time

"Man has been here 32,000 years. That it took a hundred million years to prepare the world for him is proof that is what it was done for. I suppose it is, I dunno. If the Eiffel Tower were now representing the world's age, the skin of paint on the pinnacle-knob at its summit would represent man's share of that age; and anybody would perceive that that skin was what the tower was built for. I reckon they would, I dunno" (Mark Twain)

DEEP TIME

- Relative Time approach
  - tells us the order of event, not their age
  - basic principles make it easy
  - can be done visually in the field

- Numerical Time approach
  - tells us the numerical age of rocks and/or events
  - can only be done in the lab
  - it only works on certain rocks
  - it is expensive and time-consuming



Resources: water, oil, metallic ore, etc.

The Rammelsberg mines complex in Goslar, Germany

Zinc, iron, copper, silver, gold and more have been extracted for centuries at this location at the foot of the Harz Mountains in northern Germany

Lessons from the past

2008

2015

Landslide in shales and gypsum, Borgo Tossignano, Bologna, Italy

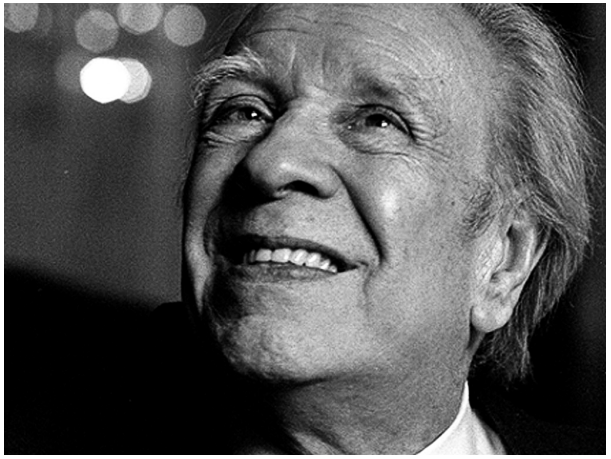
EARTH HISTORY: arrow or cycle?

- Arrow
  - History is an irreversible sequence of unrepeatable events. Time has a direction
- Cycle
  - Apparent motions are part of repeating cycles, and differences of the past will be realities of the future. Time has no direction

(Stephen Jay Gould, 1987)

"If space is infinite, we may be at any point in space.
If time is infinite, we may be at any point in time"

Thomas Burnet



Jorge Luis Borges's
paradox in
"The Book of Sand"

A beginning and an end?
It is an arrow

Repetitions?
It is a cycle

What if the cycles are slightly different, so that every repetition is actually not the same? In this way we know where we are in space, we know where we are in time.

EARTH'S SYSTEM TODAY

- **A rocky physical body**
  - Core, Mantle, Oceanic Crust, Continental Crust
- **The Water**
  - Hydrosphere
    - Salt waters: Oceans
    - Fresh waters: Glaciers, Groundwater, Rivers, Lakes
    - Water vapor in the atmosphere
- **The Air**
  - Atmosphere
    - 79% N_2, 21% O_2, traces of CH_4, CO_2, NO_2, SO_2, H_2O and other gases
- **Living organisms**
  - Prokaryotes (Archaea, Bacteria)
  - Eukaryotes (Protists, Fungi, Plants, Animals)

EARTH'S SYSTEM, always like today?

- **ROCKS**
  - formed from molten planet
  - rocks abundance, type, distribution changed over time
- **WATER**
  - not present at beginning
  - oceans became saltier in time, up to today's 34.7 ppm (3.47%)
  - glaciers were more or less abundant than today at different times
- **AIR**
  - more greenhouse gases, no O_2 at beginning
  - amount of O_2 variable in the past
- **LIVING ORGANISMS**
  - no organisms found on any other planet
  - all organisms interfere with Earth
  - organisms change in time (evolution)

Where do the components come from?

- Solid **ROCKS** formed when Earth cooled
- Liquids and gases were originally released during volcanic eruptions (**WATER** and **ATMOSPHERIC GASES**)
  - Water and air were retained thanks to gravitational force
- **LIFE** started as soon as Earth's surface was solid

WATER

- In Oceans
  - salt water; salinity is variable but the types and ratios of salt are identical all over the world in open oceans; mostly Na^+ and Cl^- ions

The Pacific Ocean: Howe Sound, by Vancouver, B.C. Canada

WATER

- In Rivers
  - fresh water; salt types and ratios may vary, depending on rock source

The Virgin River in Zion National Park
Springdale, Utah

WATER

- In Lakes
  - fresh water or salt water ; if salty, type of salt may vary

An ephemeral, saline lake: Badwater, Death Valley National Park, California

WATER

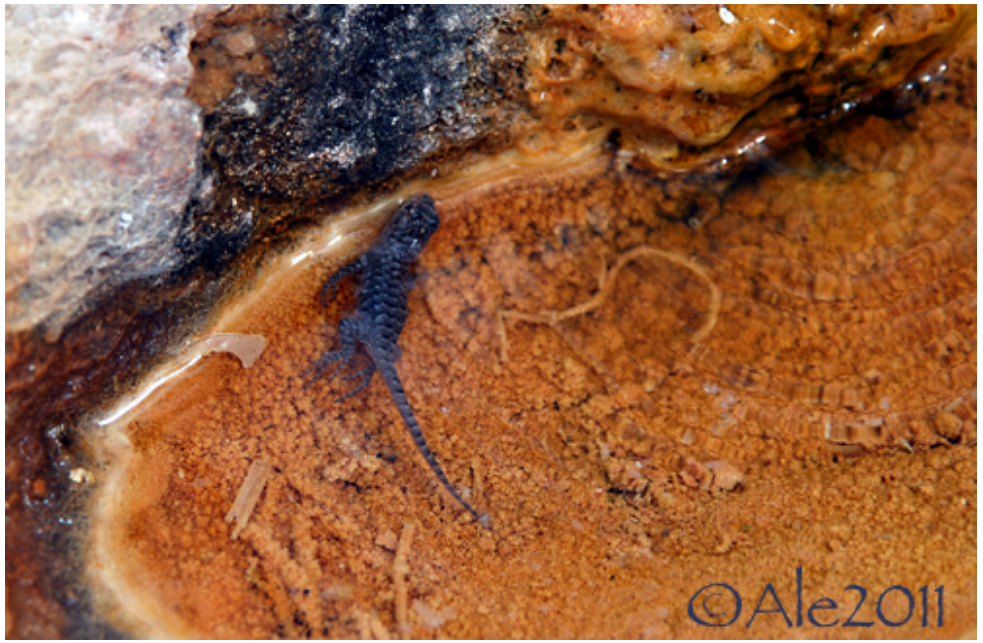
A perennial, freshwater lake
Convict Lake, Sierra Nevada, California

WATER

A “different” kind of salt water lake:
Tufa towers in the alkaline waters of
Mono Lake, Lee Vining, California

WATER

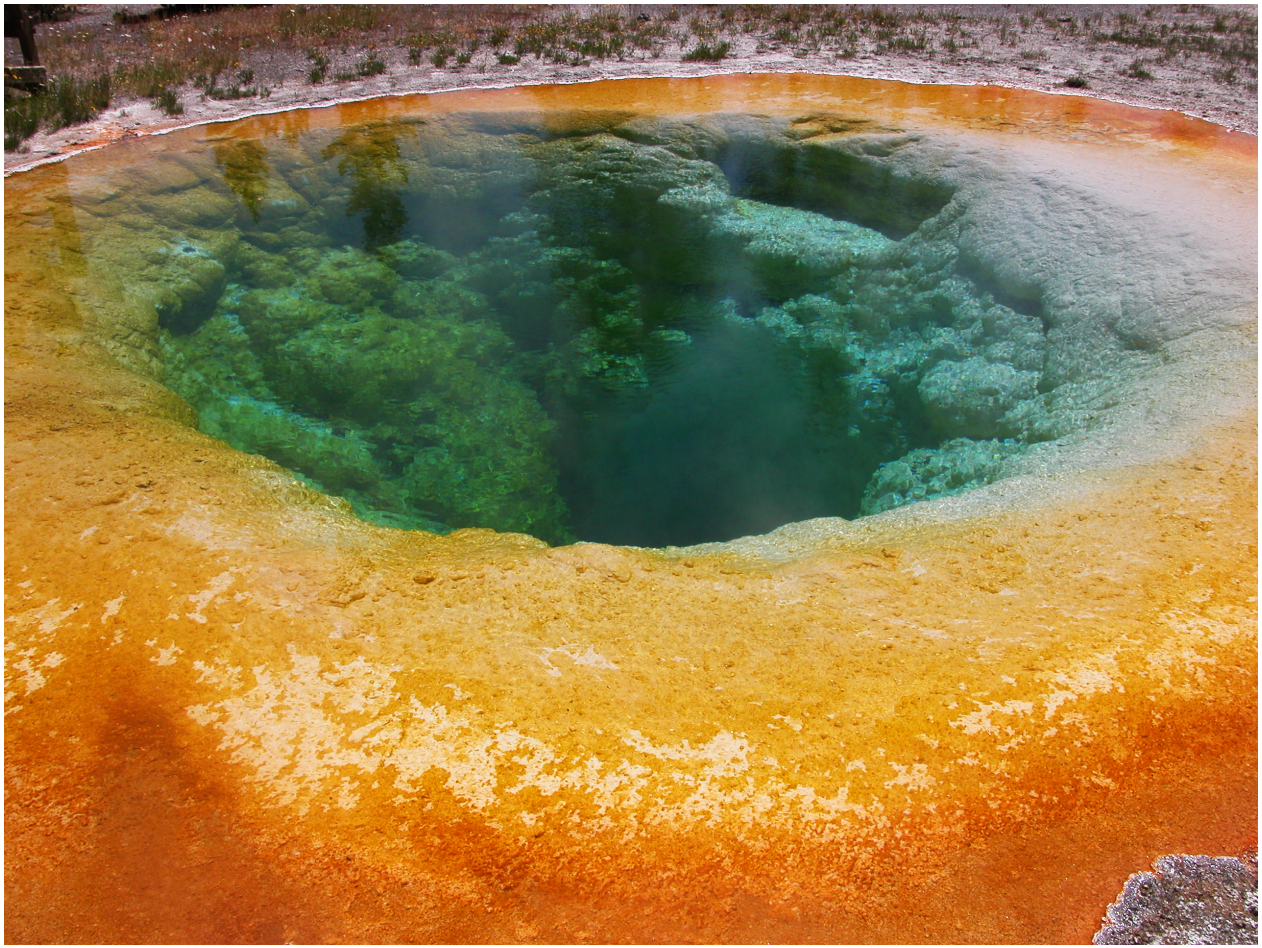
- As Groundwater
  - fresh water; can be salty close to ocean or at depth
  - temperature may vary: geothermal waters



Hot groundwater upwells at this location, killing animals who fall into pools, and causing deposition of calcium carbonate (orange crystals)

Hot Springs by Bridgewater, California

WATER



Hot water pools in **Yellowstone National Park, WY**

the colors are the result of different colonies of bacteria that thrive in progressively lower water temperatures

WATER

A geyser in Yellowstone National Park, WY

WATER

- As Ice
  - Ice on continents
  - Ice pack (sea ice), can contain up to 0.8% salt
  - Alpine ice

Glacier Bay, Gustavus, Alaska

WATER

clockwise from upper left:
the Andes at the Chile/Argentina border; the Alaska Range in Seward, AK;
a glacial cirque in the Rocky Mountains, CO; a glacier in the Coast Mountains, AK

WATER

- As Water Vapor
  - Atmospheric moisture, usually “distilled” water
  - Percentage of water in atmosphere can vary

Clouds over the island of **Maui, Hawaii**

WATER

- In Rocks
  - directly as water (e.g. Gypsum, $CaSO_4*2H_20$)
  - trapped in clay minerals
  - as OH^- (hydroxide) ions that can promptly react with H^+ ions (protons)

- In Living Organisms
  - Plants (evaporation and transpiration processes)
  - Animals

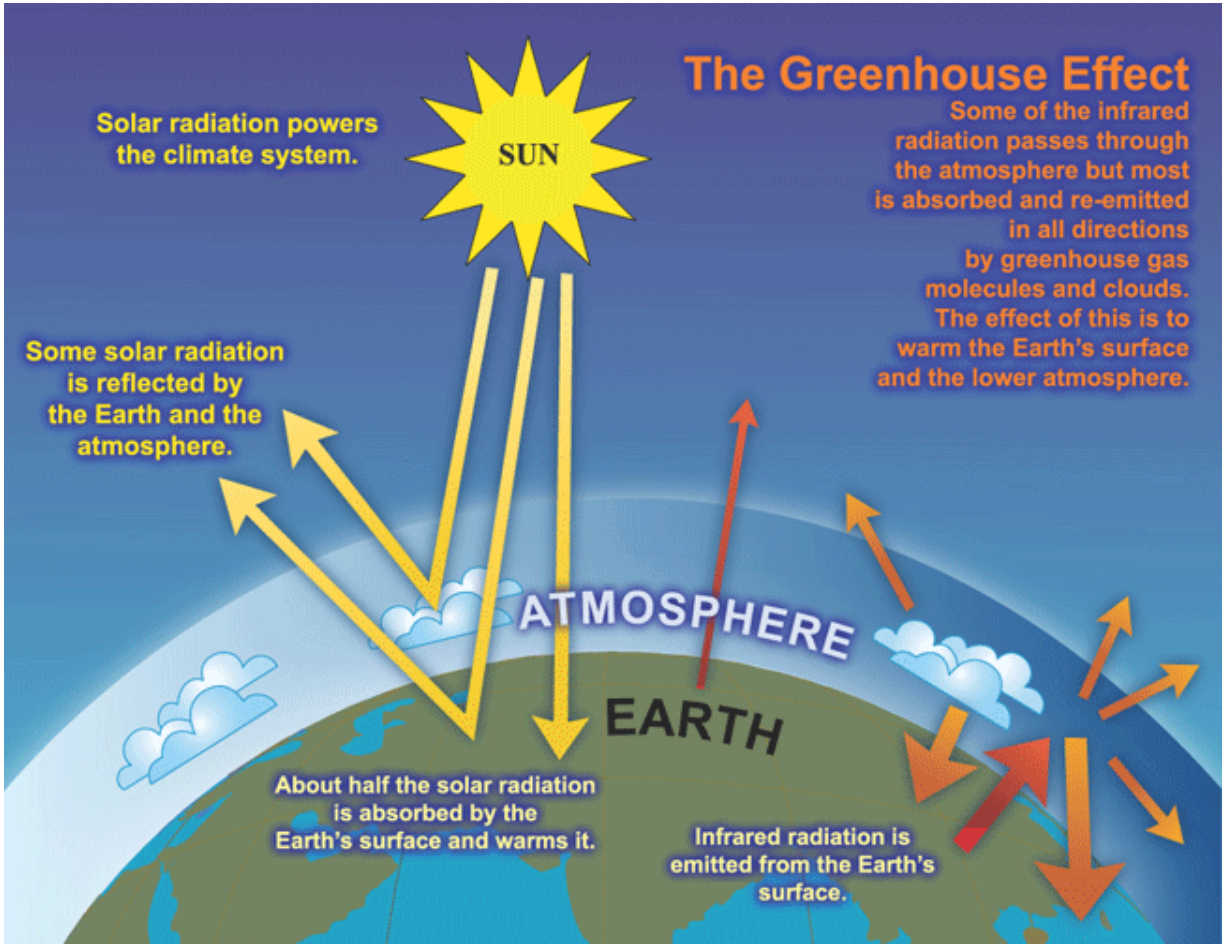
AIR

- Nitrogen: 78%
- Oxygen: 21%
- other gases: ~ 1%
  - (CO_2, NO_2, CO, NO, CH_4, H_2O, and others)

in orange: greenhouse gases

AIR

- Greenhouse gases:
  - Solar radiation can penetrate greenhouse gases
  - Radiation is reflected back by Earth, but at a different frequency
  - Greenhouse gases trap the radiation emitted by Earth
  - More greenhouse gases in the atmosphere imply warmer temperatures



from www.co2now.org

LIVING ORGANISMS

- Unique to Earth
- Appeared as soon Earth developed a solid crust
- Need energy to survive
  - from chemosynthesis
  - from photosynthesis
- Bacteria were *the only living organisms* on Earth during 85% of the time of its existence

LIVING ORGANISMS

- Started as:
  - chemosynthetic
  - prokaryotic
  - mitotic
  - single celled

LIVING ORGANISMS

- Evolved in time into:
  - photosynthetic
  - eukaryotic
  - meiotic (sexual reproduction)
  - colonial
  - from colonial to multicellular
  - from simple multicellular (e.g. sponges) to specialized multicellular (e.g. plants and animals)

LIVING ORGANISMS

- Organisms modify the environment
  - Photosynthesis
    - added oxygen to atmosphere
    - oxygen provides more energy as a fuel
    - life development sped up
  - Carbonate reefs
    - today they are limited, more developed in the past
  - Human activity

LIVING ORGANISMS

- Photosynthesis

solar energy

$$6CO_2 + 6H_20 \rightarrow C_6H_{12}O_6 + 6O_2$$

carbon dioxide + water → sugar + oxygen

- Respiration

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_20$$

sugar + oxygen → carbon dioxide + water

release of (solar) energy stored in sugar

LIVING ORGANISMS

- Destruction vs. Preservation of Organic Matter
  - oxygen is needed to burn sugars
  - upon death, bodies are recycled by scavengers, decomposers, who all need oxygen
  - if there is no oxygen, organic matter (the sugars) do not decompose and are preserved, albeit modified
  - this preserved organic matter that escaped decomposition makes for hydrocarbons (oil and natural gas)

FOSSILS

- Remnants of ancient organisms, or of their activity (trace fossils)

- Best conditions for fossil preservation:
  - rapid burial, or lack of oxygen in general
  - presence of hard, mineralized parts (bones, teeth, shells, etc.)

- Fossils are useful in for two main reasons:
  - they indicate the ancient environment of deposition
  - because of evolution by natural selection, they indicate *relative time*

And what about the Physical Earth? And Rocks?

- **PLATE TECTONICS**
  - A scientific theory that explains 99% of what we see at Earth surface, in terms of mountains, oceans, earthquakes, volcanoes, continent distribution, life forms spreading and consequences on evolution

(to be continued)