Paleoclimatology

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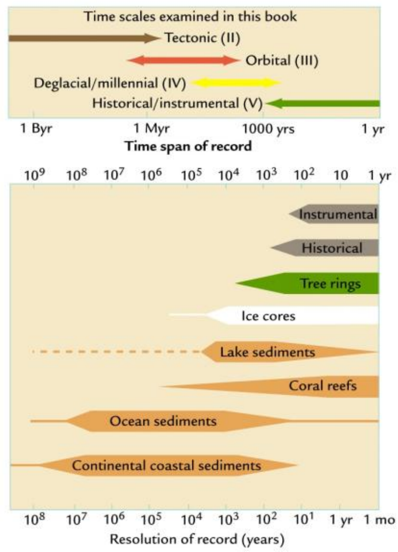
3 Objectives

- Discuss climate archives
  - Piecing the puzzle together
- Discuss key climate events using these different archives
  - Current understanding of atm evolution
- Review key time periods of interest to current warming

Time scales for Proxy Data



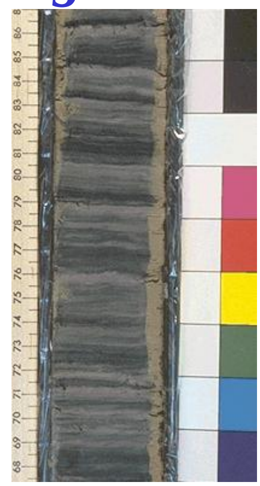
Ruddiman, 2008

Archives of Climate Change:

Geological
Biological: Fossils & Pollen
Cryological: Ice Cores
Historical
Biological: Tree-Rings
Instrumental Records

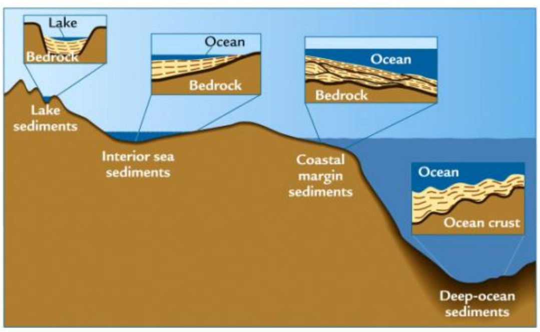
- Proxy: Using one thing in place of another...
- Always better if 2 different, independent proxies agree ☺

Archives of Climate Change:



Geological

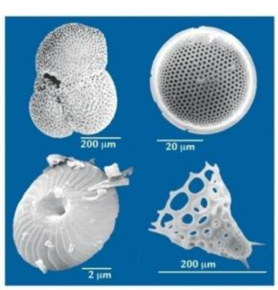
Sediment structures & material (loess)
Glacial moraines
Lake sediments
Coastal & Deep Ocean sediments



Archives:

Biological

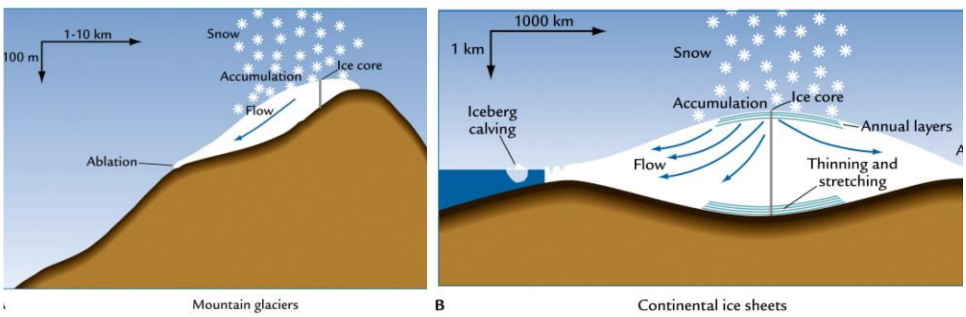
Fossils or dead material
Trees
Critters (macro: mammals, beetles, etc.
& micro: corals, plankton, forminifera, etc.)



Archives of Climate Change:

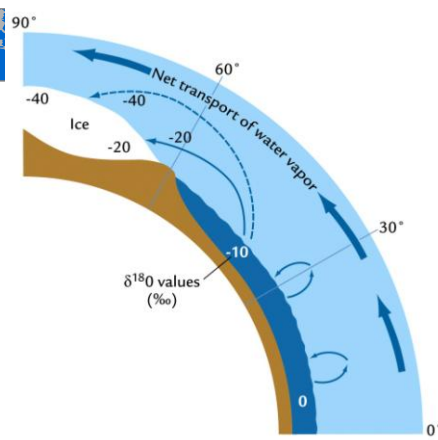
Cryological

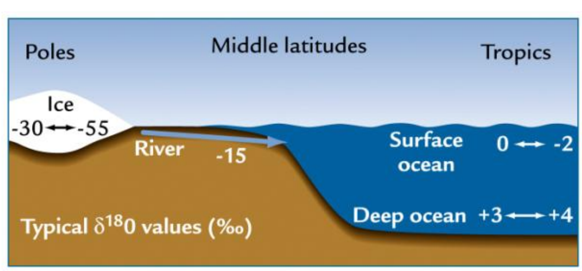
Glaciers & Ice Caps



Ice & Sediment Cores

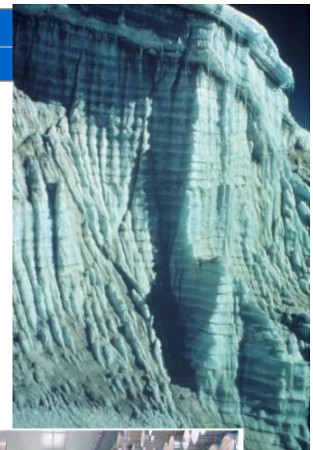
- Oxygen-isotope analysis:
  - **$\delta^{18}O$**
  - Measure ratio of ^{16}O to ^{18}O
  - Water from ocean enriched in 18 as 16 evaporates better…
  - When glaciers advance, more 16 frozen, so even more 18 in water…





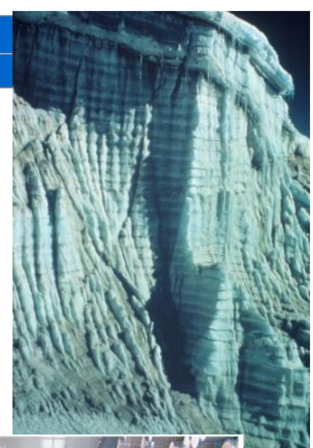
Ice Cores & Sediment Cores

- deuterium/hydrogen ratio:
  - δD‰
  - Measure ratio of ^{2}H to ^{1}H…
  - Deuterium is heavier than normal Hydrogen, so it takes more energy to evaporate any water molecule made with "heavy hydrogen".
  - The result is that the colder it gets, the less Deuterium ends up in precipitation.
  - The smaller the D/H ratio, the colder the climate.



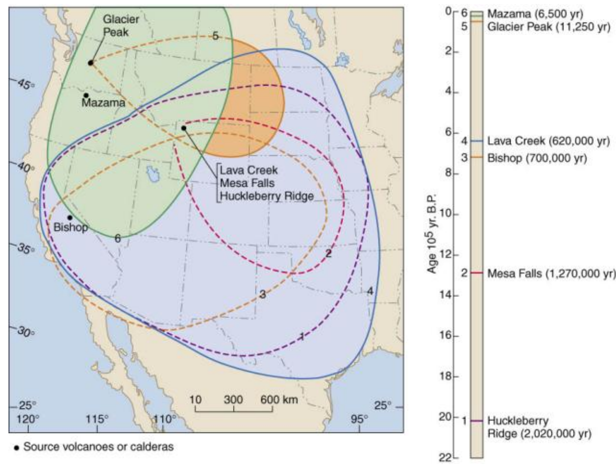
Ice Cores

- Ice cores:
  - volcanic ash
  - particulates (dust),
  - pollen,
  - chemical composition of the air trapped inside,
  - etc..



Archives

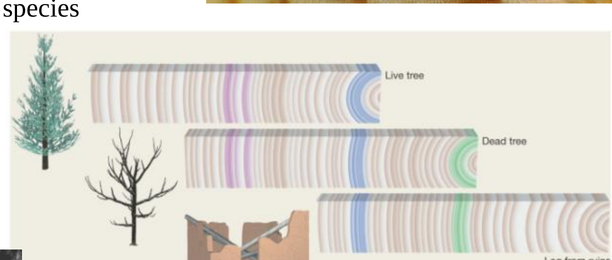
- Volcanic Ash
- Source by chemical signature
- Provides a calibration layer across variety of deposits

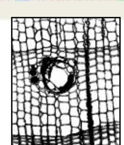


From Skinner

Tree-rings:

- Annual layers of growth
  - Depends on temp, precip, evapotrans.
  - Varies from species to species





http://web.utk.edu/~grissino/gallery.htm

Archives of Climate Change:

Historical Records

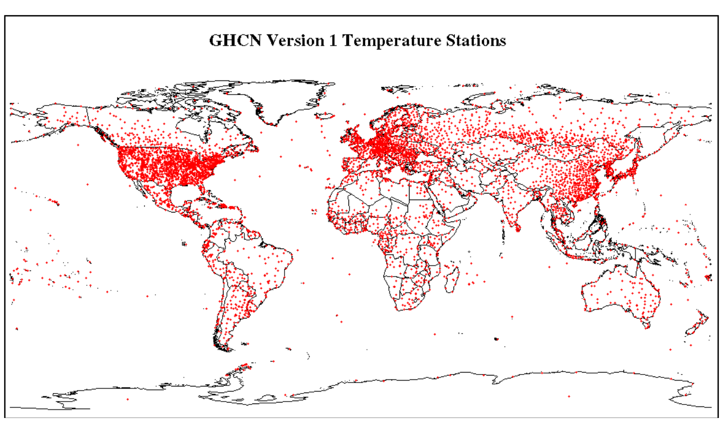
Letters, Diaries, Other Records

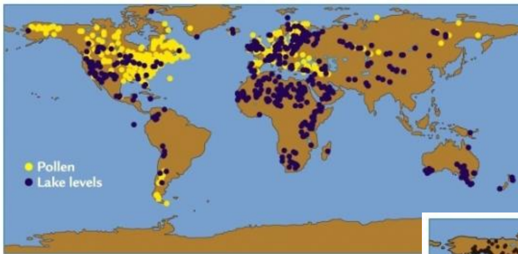
- ***Hunters in the Snow***, 1565
Pieter Bruegel the Elder
(Netherlandish, ca. 1525/30—1569)
Oil on panel; 46 1/8 x 63 7/8 in. (117 x 162 cm)
Image courtesy of the Kunsthistoriches Museum, Vienna

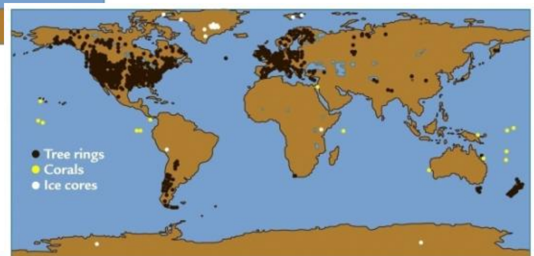
Archives of Climate Change:

Instrumental Records

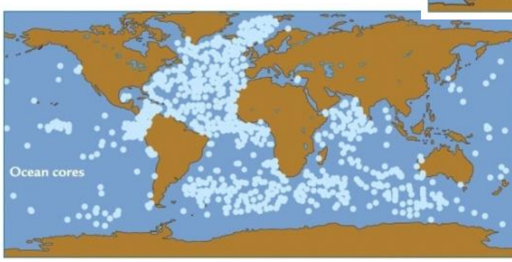
Only within last ~200 years







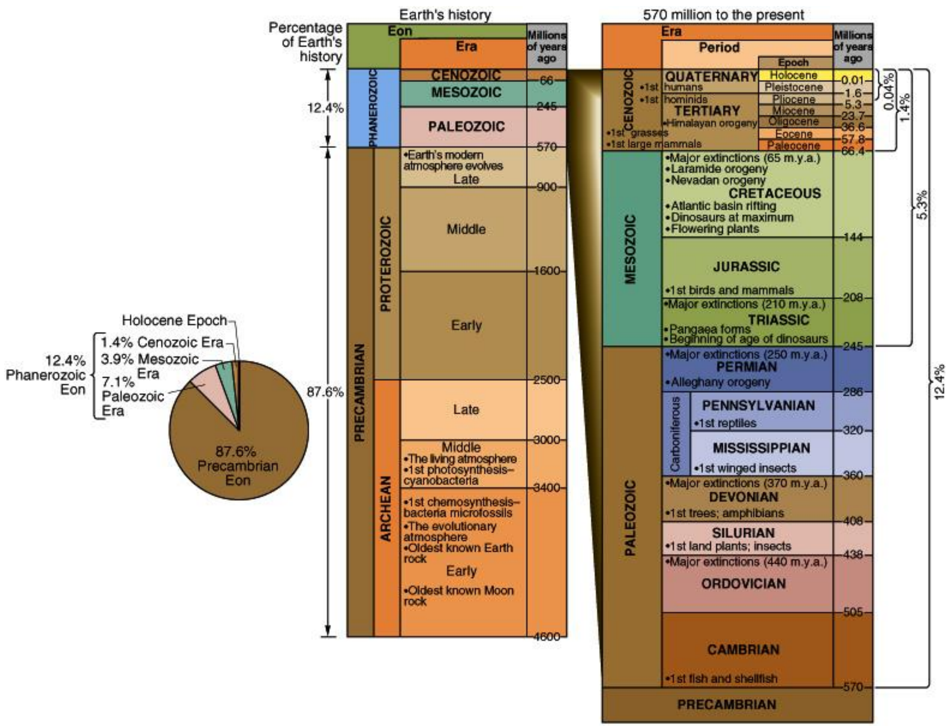
- Location, location, location!



Earth's Evolution

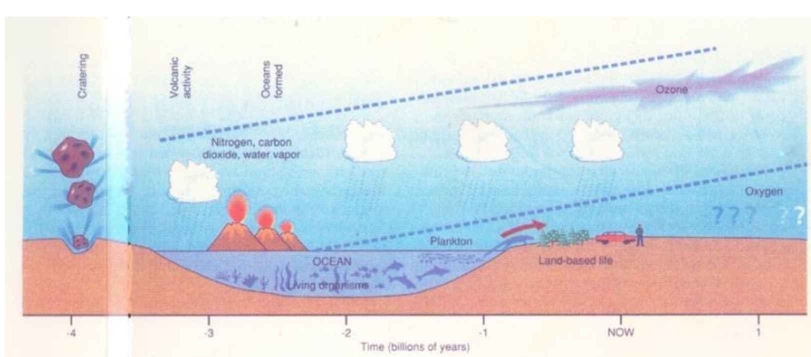
- ~4+ BYA: All blown away
- ~4: Magnetic field forms & atm held in place – no O_2
- ~3.8: Out-gassing continues but liquid earth possible as planet cools below 100 C
- ~3.5 BYA: First life forms release O_2
- ~500 MYA: O_2 levels high enough for ozone layer & plants & animals can now colonize land

- **All from geological evidence!!**



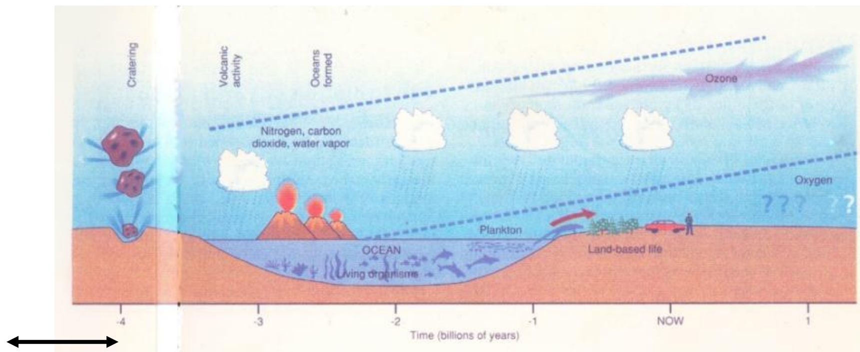
Earth's Primordial Atmosphere

- 4+ billion years ago (Y.A.)
- Consisted of gases most abundant in solar system, hydrogen and helium (lightest elements)
- Mainly blown away



Earth's Primordial Atmosphere

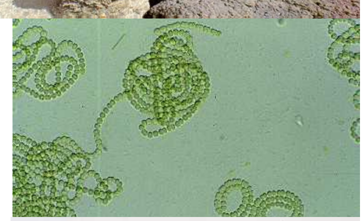
- 4+ Billion Y.A.
- Begins build up once magnetic field developed
- Consists of CO_2, NO*, H_2O



Stromatolites

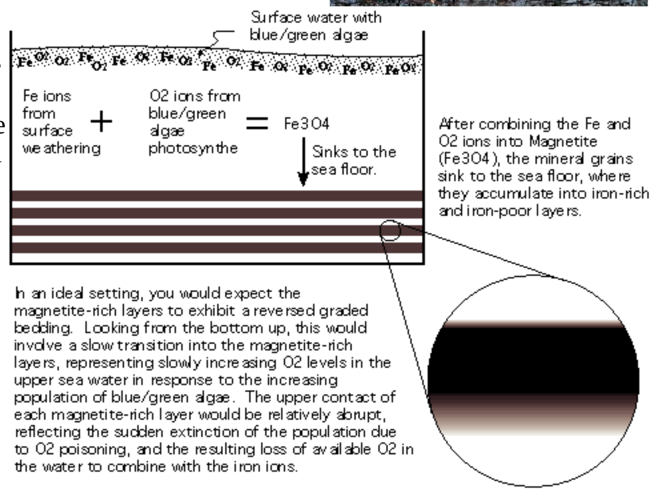
Photosynthesis

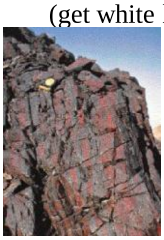
- $CO_2 + H_2O + \text{light} \rightarrow CH_2O + O_2$
- Cyanobacteria (Eubacteria) aka blue-green algae, appear ~ 3.5 bya
    - Release O_2 as byproduct
- Accumulation of O_2 in the atmosphere didn't start until oceanic Fe_2+ was oxidized (~2 bya).



Banded Iron Formations

- Water with O_2 (from blue-green algae) & Fe from surface weathering.
- Get deposits (iron-rich layer) This cleans algae's environment.
- Too much algae, produce too much O_2, not enough Fe to remove it…
- O_2 toxic to algae, population collapse… (get white layer)





The red bands are hematite, and are interbedded with chert.

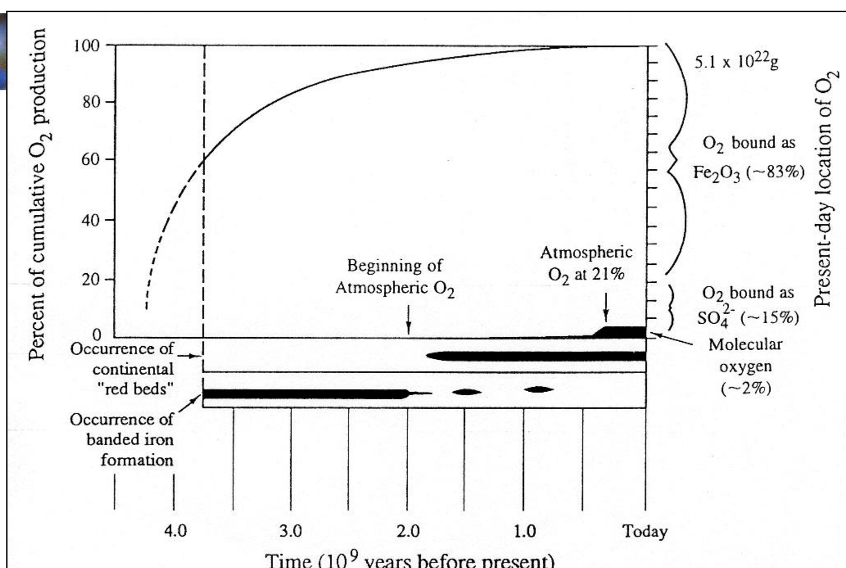


Figure 2.7 Cumulative history of O_2 released by photosynthesis through geologic time. Of more than 5.1×10^{22} g of O_2 released, about 98% is contained in seawater and sedimentary rocks, beginning with the occurrence of Banded Iron Formations at least 3.5 billion years ago (bya). Although O_2 was released to the atmosphere beginning about 2.0 bya, it was consumed in terrestrial weathering processes to form Red Beds, so that the accumulation of O_2 to present levels in the atmosphere was delayed to 400 mya. Modified from Schidlowski (1980).