Geol 437 The "slow" (geologic) carbon balance

1. Silicate weathering:
   \[ \text{CO}_2 + (\text{Ca}, \text{Mg})\text{Si}_3\text{O}_5 \rightarrow (\text{Ca}, \text{Mg})\text{CO}_3 + \text{SiO}_2 \]

2. Organic burial/net photosynthesis:
   \[ \text{n CO}_2 + \text{n H}_2\text{O} + \text{energy} \rightarrow \text{C}_n\text{H}_{2n}\text{O}_n + \text{n CO}_2 + \text{n H}_2\text{O} + \text{energy} \]

3. Magmatic degassing:
   \[ (\text{Ca}, \text{Mg})\text{CO}_3 + \text{SiO}_2 \rightarrow \text{CO}_2 + (\text{Ca}, \text{Mg})\text{Si}_3\text{O}_5 \]

4. Net oxidation/metamorphic degassing:
   \[ \text{C}_n\text{H}_{2n}\text{O}_n + \text{nO}_2 \rightarrow \text{n CO}_2 + \text{n H}_2\text{O} + \text{energy} \]

Geologic ("slow") carbon balance (average over ~10^7 years):

Removal of CO2 by silicate weathering, organic burial/net photosynthesis = addition of CO2 by magmatic/metamorphic degassing, net oxidation

Berner (1999)
A reservoir is a quantity to which (from which) we can add (or subtract), increasing (decreasing) its size.

- Bank account
- Ocean
- Living things ("biota")
- Atmosphere
- Freshwater reservoir

Synonyms: "sink", "pool"

\[ 6 \times 10^7 \text{ GtC} = 6 \times 10^7 \times 10^9 \text{ tons C} = 6 \times 10^7 \times 10^9 \times 10^3 \text{ kg C} \]

A reservoir flux is a rate at which a quantity is moving into or out of a reservoir.

In steady state (balance), reservoir flux in = reservoir flux out:

Residence time = \[ \frac{\text{reservoir size}}{\text{reservoir flux (in or out)}} \]

= average time a quantity remains in that reservoir.

\[ \text{Carbonate Rocks} \quad 6 \times 10^7 \text{ GtC} \]

\[ \text{Weathering flux} \quad 0.2 \text{ GtC/yr} \]
Geol 437: “Fast” carbon chemistry

1. Photosynthesis and respiration/decomposition:

\[ C_nH_{2n}O_m + nO_2 \xrightleftharpoons{\text{photosynthesis}} nCO_2 + nH_2O + \text{energy} \]

Net primary productivity: photosynthesis - respiration - decomposition

2. Ocean carbon chemistry:

- Concentration of CO\(_2\) dissolved in the ocean is:
  - directly proportional to atmospheric CO\(_2\) concentration (Henry's Law)
  - inversely proportional to temperature

- CO\(_2\) “buffer” chemistry:
  \[ H_2O + CO_2(aq) + CO_3^{2-}(aq) \rightleftharpoons 2HCO_3^-(aq) \]

- Calcium carbonate chemistry:
  \[ H_2O + CO_2(aq) + CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + 2HCO_3^-(aq) \]
  - Law of Mass Action: reaction rates are proportional to concentration of reactants, raised to their stoichiometric power
Geo 147: "Fast" carbon balance

**Atmosphere**

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800 GtC
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**Human activities**
- Combustion production: +3 GtC/yr
- Land use change: +3 GtC

**Siocle weathering**
- 0.4

**Ocean**
- Surface
  - Marine biota
    - Photosyn: 50 GtC
    - Resp.: 100 GtC
- Deep
  - Net marine export: 0.2 GtC
  - Net sedimentation: 0.2 GtC

**Land**
- Plant photosynthesis: 120 GtC/yr
- Plant resp. + decompos.: 60 GtC
- Soil C: 2300 GtC
- Net terrestrial uptake: 0.4 GtC
- Fossil C: 10000 GtC

**Magmatic/metamorphic degassing**
- 0.2 GtC

**Land**
- Plant biomass: 550 GtC
- Net terrestrial uptake: 0.4 GtC
- Soil C: 2300 GtC
- Fossil C: 10000 GtC

**Ocean**
- Surface
  - Marine biota
    - Photosyn: 50 GtC
    - Resp.: 100 GtC
- Deep
  - Net marine export: 0.2 GtC
  - Net sedimentation: 0.2 GtC

**Sediments**
- "Reactive" layer
- 6000 GtC

References: