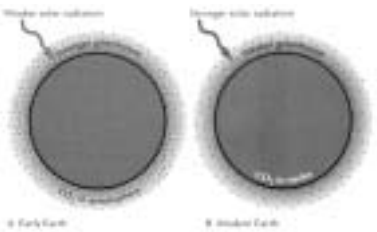
Lecture 9: Faint Young Sun Paradox



(from *Earth's Climate: Past and Future*)

- Carbon Cycle As a Thermostat for Earth
- Chemical Weathering and Continental Drift
- Why No Similar Thermostat on Venus and Mars

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Faint Young Sun Paradox

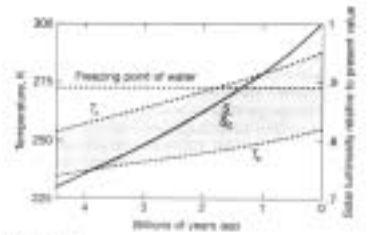

FIGURE 8.8

(from *The Earth System*)

- Solar luminosity was much weaker (~30%) in the early part of Earth's history (a faint young Sun).
- If Earth's albedo and greenhouse effect remained unchanged at that time, Earth's mean surface temperature would be well below the freezing point of water during a large portion of its 4.5 Byr history.
- That would result in a "snowball" Earth, which was not evident in geologic record.

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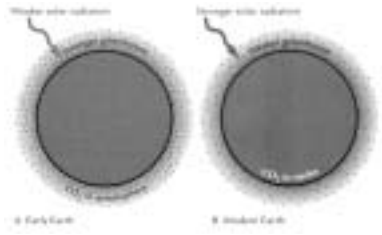
Earth's Thermostat – Chemical Weathering



(from *Earth's Climate: Past and Future*)

- Chemical weathering acts as Earth's thermostat and regulate its long-term climate.
- This thermostat mechanism lies in two facts:
  (1) the average global rate of chemical weathering depends on the state of Earth's climate,
  (2) weathering also has the capacity to alter that state by regulating the rate which CO_2 is removed from the atmosphere.

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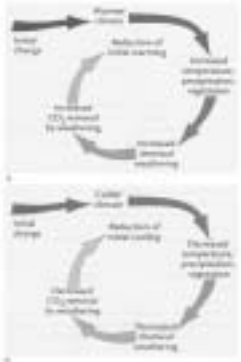
Negative Feedback From Chemical Weathering



(from *Earth's Climate: Past and Future*)

- The chemical weathering works as a negative feedback that moderates long-term climate change.
- This negative feedback mechanism links CO_2 level in the atmosphere to the temperature and precipitation of the atmosphere.
- A warm and moist climate produces stronger chemical weathering to remove CO_2 out of the atmosphere → smaller greenhouse effect and colder climate.

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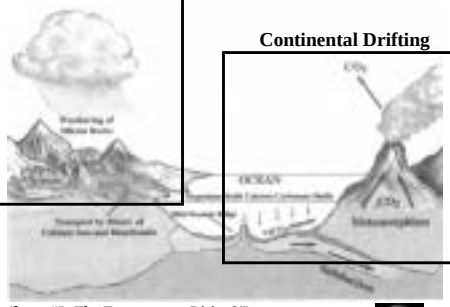
Carbon Cycling Between Atmosphere and Earth

from atmosphere to solid Earth

Chemical Weathering

from solid Earth to atmosphere

Continental Drifting



(from "*Is The Temperature Rising?*")

Plate Tectonics

- *Continental Drifting Theory*

  Alfred Wegener proposed that all the continents were once assembled into a supercontinent (Pangea) and then broke and slowly drifted to their current positions.

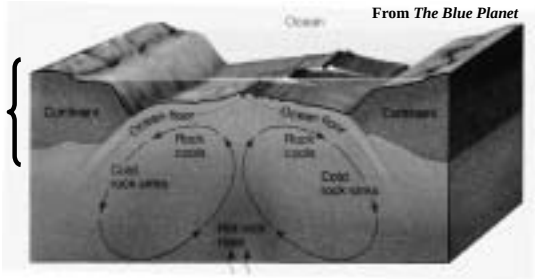
- *Plate Tectonics*

  The branch of tectonics that deals with the processes by which the lithosphere plates move and interact with each other is called plate tectonics.

Circulation of the Solid Earth

From *The Blue Planet*

Cold Lithosphere



- The rising hot rocks and slid-away flows are thought to be the factor that cont5rol the positions of ocean basins and continents.

➔ The convection determines the shape of the Earth.

Twenty Rigid Plates

From *The Blue Planet*

- What can happen to the cold boundary?

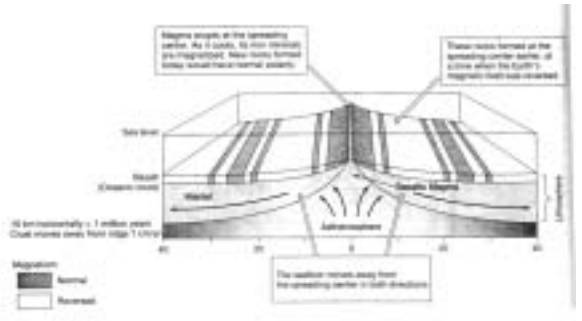
➔ The lithosphere has broken into a number of rocky pieces, called plates.

- There are six large plates plus a number of smaller one comprise the Earth's surface (a total of 20 plates).
- The plates range from several hundred to several thousand kilometers in width.

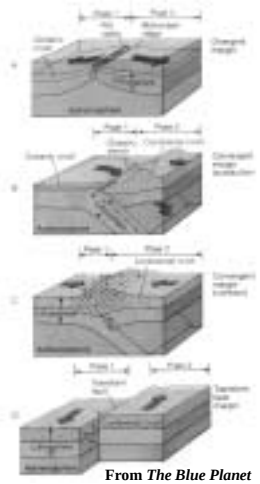
The Theory of Plate Tectonics

- A major problem of the continent drifting theory is: *How could the continents drift through the rigid sea floor?*
- This problem is answered by the seafloor spreading hypothesis: Continents do not plow through the sea floor. *Continents and segments of ocean floor are connected into plates that continuously move away from one another at mid-ocean ridges.*

Seafloor Spreading



(from *The earth System*)



From *The Blue Planet*

Plate Margins

- Interactions between plates occur along their edges. There are three types of plate margins:

(1) Divergent margins

form mid-ocean ridges (over oceans) and rift valleys (over lands)

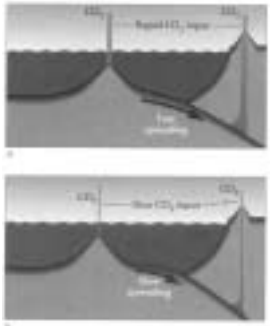
(2) Convergent margins

form deep-sea trenches (two oceanic plates or ocean+continental plates) or high mountains (such as Tibetan Plateau) (two continental plates).

(3) Transform fault margins

form earthquake faults

Tectonic Control of CO_2 *Input* – The Seafloor Spreading Rate Hypothesis



(from *Earth's Climate: Past and Future*)

- During active plate tectonic processes, carbon cycles constantly between Earth's interior and its surface.
- The carbon moves from deep rock reservoirs to the surface mainly as CO_2 gas associated with volcanic activity along the margins of Earth's tectonic plates.
- The centerpiece of the seafloor spreading hypothesis is the concept that changes in the rate of seafloor spreading over millions of years control the rate of delivery of CO_2 to the atmosphere from the large rock reservoir of carbon, with the resulting changes in atmospheric CO_2 concentrations controlling Earth's climate.

Why No Thermostat on Mars?

- **Mars is too small in size**
- ➔Mars had no large internal heat
- ➔Mars lost all the internal heat quickly
- ➔No tectonic activity on Mars
- ➔Carbon can not be injected back to the atmosphere
- ➔Little greenhouse effect
- ➔**A very cold Mars!!**

Why No Thermostat On Venus?

- **Venus is too close to the Sun**
- ➔ Venus temperature is very high
- ➔ Very difficult for Venus's atmosphere to get saturated
- ➔ Evaporation keep on bringing water vapor into Venus's atmosphere
- ➔ Greenhouse effect is very large
- ➔ A "run away" greenhouse happened on Venus
- ➔ Water vapor is dissociated into hydrogen and oxygen
- ➔ Hydrogen then escaped to space and oxygen reacted with carbon to form carbon dioxide
- ➔ **No water left on Venus (and no more chemical weathering)**