Geochemistry GG325
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http://www.soest.hawaii.edu/krubin/gg325.html

Text:

Reading assignments from various books are provided to you FOR FREE (these will be in a folder outside of my office).

grading policy…..

Grading: on a curve.
Midterm exam (25%)
problem sets (30%)
class journal (20%)
final exam (25%)

Class participation/attendance is not mandatory, but is taken into consideration in borderline grading situations.

Please turn homework assignments in on time. Grading penalties of 10% per day will apply unless a valid reason for a late assignment is discussed with me ahead of time.

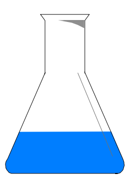
Introductory Remarks

This semester we will use Chemistry to understand:

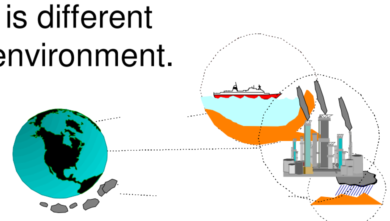
1. **the natural workings of the Earth:**
natural distributions of chemicals in global and local environments.

2. **the formation and history of the Earth:**
The birth of matter in our solar nebula, formation of the solar system and early Earth history.

3. **perturbations caused by humans:**
chemical distributions in anthropogenically "perturbed" systems (using chemical fundamentals to explain the condition of the environment there).



Chemistry in a beaker is different than chemistry in the environment.



The latter is more complex, so we make approximations and adaptations to the "standard rules".

What is Geochemistry?

Geochemistry is the study of the sources and fates of chemical species in natural environments.

Geochemistry is a set of tools for helping to understand the Earth

these tools are based upon chemical, instead of the physical observations of the geologist.

Understanding something about the chemistry of matter and the parameters that affect it help us to explain how a natural environment functions.

What is Environmental Geochemistry?

It is the study of the chemical species in natural environments and the effects of technology upon them.

Environmental Geochemistry involves the comparison of natural systems with those affected by human activities.

Humans can alter the environment physically:

i.e., they can cause excess erosion that in turn silts a river, which in turn causes water clarity and light transmission to go down, which can affect the temperature and chemistry of the riverine system (and therefore its biology as well).

Humans can also alter the environment chemically:

i.e., they can add materials to an environment which changes the way it functions by affecting either its biota or its natural chemical condition (e.g., pH).

This class will be focus on how natural environments work,

but it will also consider if and how aspect(s) have somehow been altered by human activity.

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Some Definitions

When humans add something to an environment, the added entity is known as a *Contaminant.*	
	a contaminant is a substance present in greater than natural concentration as a result of human activity that causes deviations from the normal composition of the Environment.
A contaminant is a *Pollutant* when it harms the environment	
	a Pollutant is a substance present in greater than natural concentration as a result of human activity that has a net detrimental effect upon the Environment or one of its components.
A Pollutant becomes *Toxic* (a "toxicant") when it harms one or more biota within the environment.	
	a Toxic Pollutant is a substance present in greater than natural concentration as a result of human activity that has a net detrimental effect upon the life functions of one or more biota of a given Environment.

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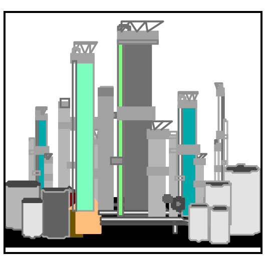
Natural Vs. Anthropogenic Compounds

- Human activities have introduced significant quantities of some completely new compounds into the environment - substances that simply did not exist on Earth prior to the Industrial Age [(CFCs, probably PCBs], making the very presence of these compounds "anthropogenic".
- Naturally occurring compounds (and elements) can also be classified as contaminants and pollutants.

  Here we talk about "anthropogenic" enrichment above "normal" levels.

This brings up a related point:
human technology has irreversibly changed the way the Earth and it's surfice sub-systems function.



Technology has changed the way in which energy and material is utilized and transferred between the various reservoirs on Earth's surface.

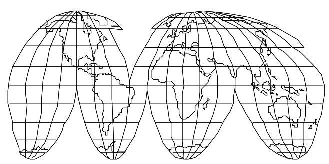
Technology has provided us with a means to improve the conditions of our lives.

Technology has also provided us with a means for dramatically altering our environment, sometimes very detrimentally.

In some cases the actions of many people put an environment "on edge", so that the subsequent actions of an individual might cause greater harm than if the environment had not previously been compromised.

Cycles of Matter

The combined forces of nature and humans cause materials to move about Earth from place to place. This movement of matter often includes chemical transformations conducted by geologic, hydrologic, atmospheric or biologic agents.



In this course we will study Earth as a *system of inter-related parts*

We will apply chemistry to geologic, hydrologic, biologic and atmospheric phenomena

AND ALSO to the relationships between them.

We will explore most of the architecture of Earth's natural cycles (interactions between hydrosphere, lithosphere, biosphere and atmosphere).

Cycles of Matter

The more we understand of natural cycles, the better equipped we are to avert future problems caused by our continuing industrialization, which usually involves altering the natural order of things.

Earth Scientists often find it convenient to think of various parts of our planet as containers between which matter moves.

- These containers are referred to as *Reservoirs*.
- Movement of material between them is known as a *flux*.
- Concentration changes in space and time are determined by

Transport equations

Definition of Reservoirs

any physical subdivision of the natural world that acts semi-independently and in which one or more classes of processes occur.

We can define reservoirs differently depending upon the problem we are studying.

- *i.e., the hydrosphere might be defined as the location of all water on Earth*
- *the exogenic hydrosphere would be only the "surface" water;*
- *sub-reservoirs can also be defined, such the oceans, rivers, glaciers, lakes, etc...)*

Interaction between the major reservoirs on Earth follow predictable *Cycles*.

Definition of Cycles

The pathways and rates of material or energy transfer between reservoirs are cycles. Ideally, a cycle is "closed" so that all material is accounted for in the mass balance.

Definition of Biogeochemical Cycles

the chemical interactions between various abiotic reservoirs and biological life.

Definition of Geobiology

the study of the modern and past geological record from the perspective of interactions with, and effects of, biological life.

Cycles can apply to parts of the earth that we conveniently define to suit our purposes. A lake is a very clear example of a "reservoir". Many physical and chemical processes take place in the lake waters. The waters of the lake exchange matter with the surrounding environment (the atmosphere, the underlying sediments and via rivers, streams and groundwater that flow in and out).

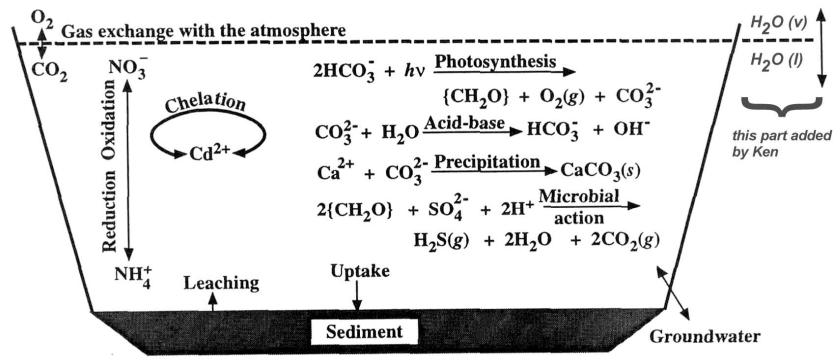
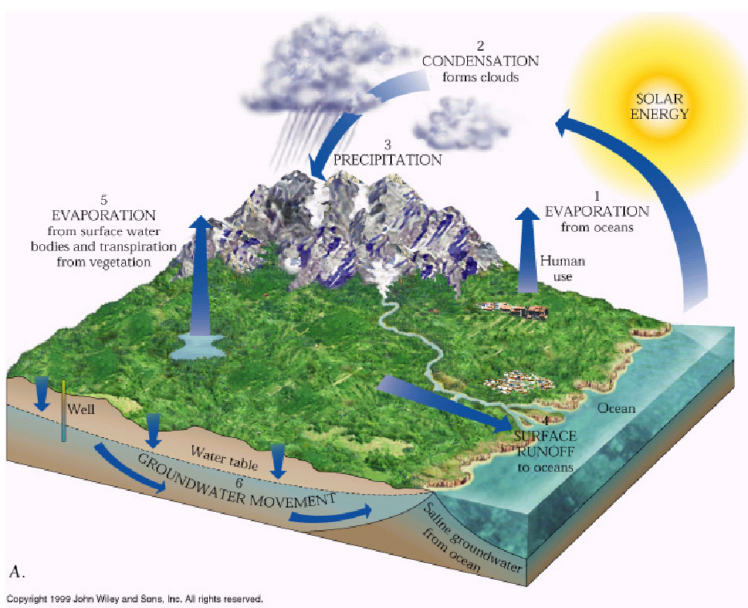
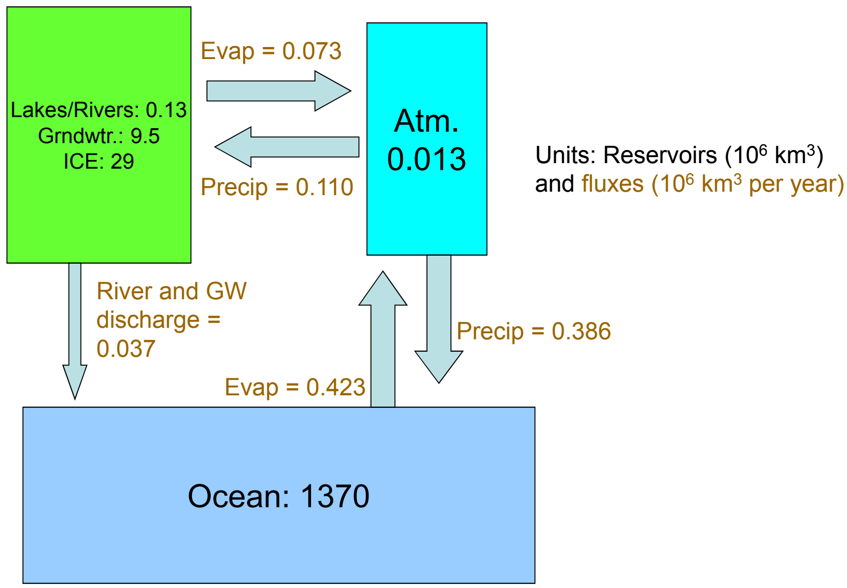


Figure 3.7. Major aquatic chemical processes. *Modified from Manahan*

In geology 101 you likely saw cartoons of the hydrologic cycle like this one



With the concepts of reservoirs, fluxes and cycles we can treat the global hydrologic cycle in a more quantitative way.



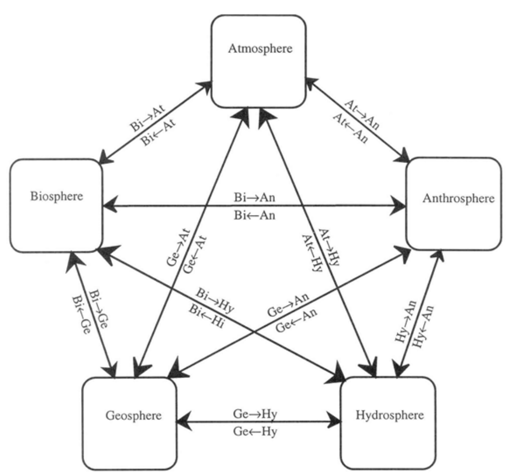


Figure 1.3. General cycle showing interchange of matter among the atmosphere, biosphere, anthrosphere, geosphere, and hydrosphere.

In a generic "cycle" diagram reservoirs are boxes and fluxes are arrows. We quantify reservoirs with units of mass or concentration and fluxes with units of mass or concentration per time.

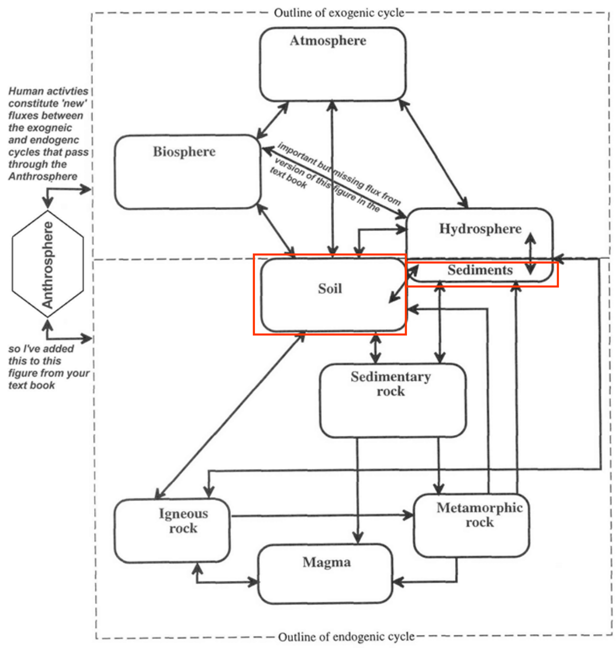


Figure 1.4. General outline of exogenic and endogenic cycles. *Modified from Manahan*

Soil is often included in the exogenic cycle but this figure from your text places it entirely within the endogenic cycle.

Also, an important hydrosphere-biosphere flux is not shown in this figure.

Notice that "Technology", aka the "anthrosphere", is also not included in this subcycle map.

Yet the anthrosphere feeds into and draws from both.

Can you think of ways how?

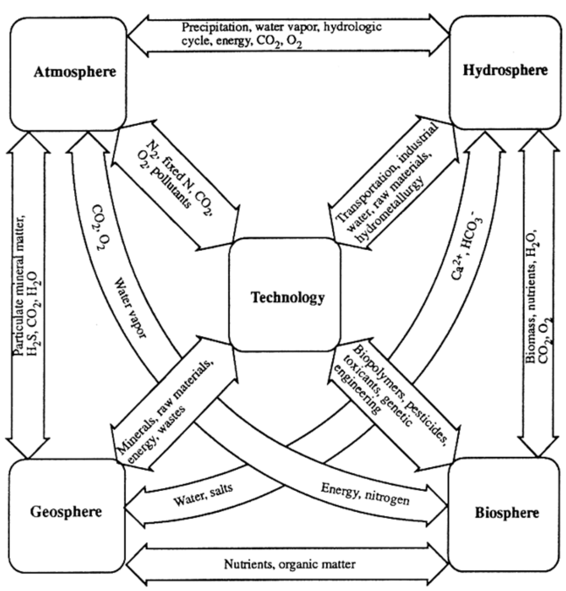
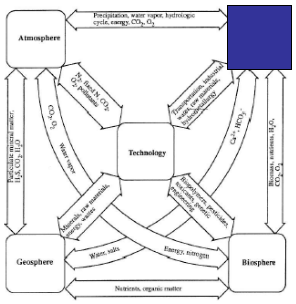


Figure 1.1. Illustration of the close relationships among the air, water, and earth environments with each other and with living systems, as well as the tie-in with technology.

This is a general cycle diagram.

It illustrates four major Earth reservoirs and identifies some of the fluxes to and from these various reservoirs.

It also illustrates human impacts on them (the so called “technology” reservoir).



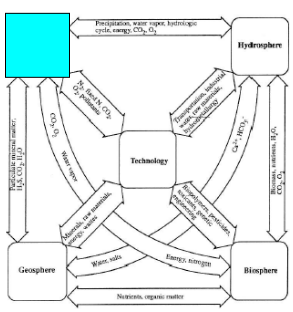
The Hydrosphere

We will talk about the hydrosphere a lot. What is it?.

Is water vapor in the atmosphere part of the hydrosphere or part of the atmosphere?

Is the water in your body part of the hydrosphere?

The answers to these depend on how we define the reservoir to study specific aspects of material flow.



The Atmosphere

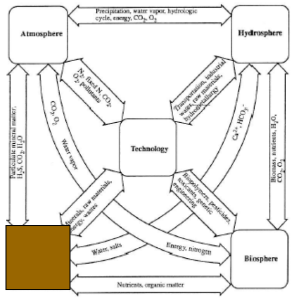
The thin layer of gases that blanket the Earth's surface.

A very "intuitive" example of a reservoir:

Obvious compositional contrast, and physical location clearly differentiates the atmosphere from the rest of the Earth

Or does it? How about pore spaces in soils? Are they part of the atmosphere?

This is up to the person defining the cycle to some extent but it is unlikely that one would choose to include the gases in soil pore spaces as part of the atmosphere. *Why do you think this is the case?*



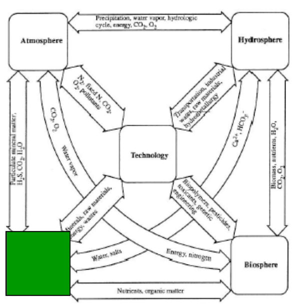
The Geosphere

In the text it is stated that the geosphere is the realm of the solid Earth, including soils. This is a big hunk of material to lump into one reservoir.

In this course there will be little or no discussion of the deep earth.

Our emphasis will be on surface processes - that part of the geosphere which is connected to the exogenic cycle.

But we will consider rocks, soils and sediments separately.



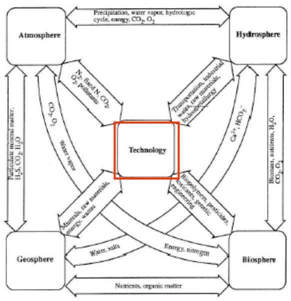
The Biosphere

The sum total of all living entities on the Earth.

Life resides in the hydrosphere, geosphere and atmosphere.

Frequently the biosphere (living biomass) is considered as a separate reservoir from those:
e.g., the living part of a forest, living plankton in the ocean.

A key aspect of the biosphere is its ability to create “stored chemical” energy through processes such as photosynthesis.



The Anthrosphere

The effects of human activity are greatly amplified by technology.

The chemical signatures of human activity touch nearly every part of globe.

This table is a flux matrix (i.e., it gives some examples of the types of materials that are transferred between the major reservoirs).

It only scratches the surface of the very complex multi-component fluxes between them.

Table 1.1. Interchange of Materials among the Possible Spheres of the Environment

From / To	Atmosphere	Hydrosphere	Biosphere	Geosphere	Anthrosphere
Atmosphere	---	H_2O	O_2	H_2S, particles	SO_2, CO_2
Hydrosphere	H_2O	---	{C H_2O}	Mineral solutes	Water pollutants
Biosphere	O_2, CO_2	H_2O	---	Mineral Nutrients	Fertilezer
Geosphere	H_2O	H_2O	Organic Matter	---	Hazardous Wastes
Anthrosphere	O_2, N_2	H_2O	Food	Minerals	---

Intro to Global Element cycles

- Ideally these must be “closed” (all material is accounted for).
- Examples of a few particularly important element cycles follow.
- Diagrams need not include all “spheres”, and often contain subdivided “spheres” (oceans from fresh water, etc.)

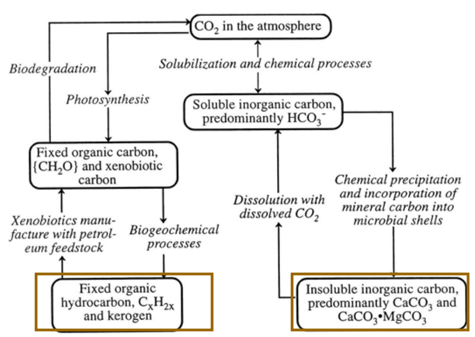


Figure 1.5. The carbon cycle. Mineral carbon is held in a reservoir of limestone, $CaCO_3$, from which it may be leached into a mineral solution as dissolved hydrogen carbonate ion, HCO_3^-, formed when dissolved $CO_2(aq)$ reacts with $CaCO_3$. In the atmosphere carbon is present as carbon dioxide, CO_2. Atmospheric carbon dioxide is fixed as organic matter by photosynthesis, and organic carbon is released as CO_2 by microbial decay of organic matter.

In this rendition of the carbon cycle, one must infer missing reservoir "names". For instance boxes for "fixed organic fossil carbon" and for "insoluble inorganic carbon" represent the **GEOSPHERE**.

Can you identify the hydrosphere and biosphere boxes?

This rendition of the nitrogen cycle contains hybrid reservoirs

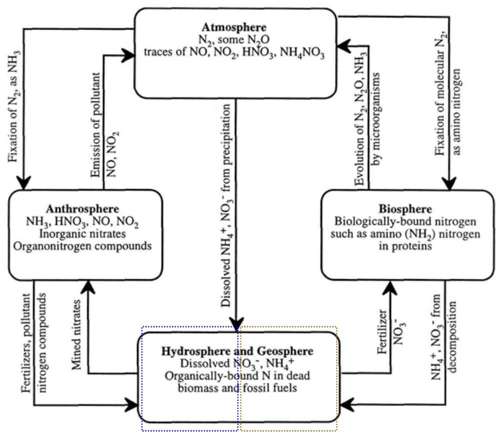


Figure 1.6. The nitrogen cycle.

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