Energy → Geology

22 January 2007
5th class meeting

- Energy basics
- Geology overview

22 Jan READINGS:
Withgott & Brennan [2007paperback] excerpt
Geology reading (by Chronic) on website
Wednesday 24 Jan:
Ricklefs Ch7 – Ecosystems and Nutrient Cycling

Lab 24/26 Jan:
Ishmael for lab on 24 or 26 January (questions on website)
Lab 31 Jan/ 02 Feb:
Ecological Footprint

Environmental Biology (ECOL 206)
University of Arizona, spring 2007

Kevin Bonine, Ph.D.
Anna Tyler, Graduate TA

http://eebweb.arizona.edu/courses/Ecol206/206_Page2007.html

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Energy

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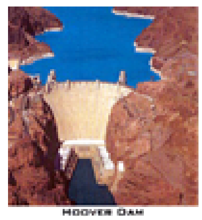
Energy can…

1. Change position
2. Change physical composition
3. Change temperature

… of matter

Potential Energy (of position)

Kinetic Energy (of motion)



Energy, 1st and 2nd Laws of Thermodynamics, Entropy

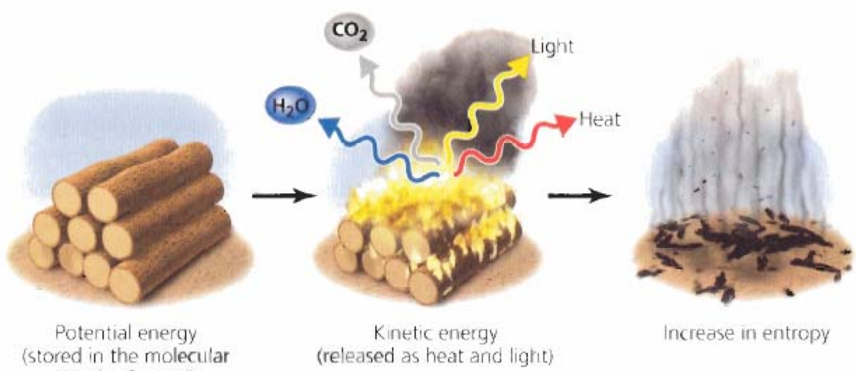


FIGURE 3.8 The burning of firewood demonstrates energy transfer leading from a more-ordered to a less-ordered state. This increase in entropy reflects the second law of thermodynamics.

Energy Quality

Withgott&Brennan (2007)

First law of thermodynamics:

Energy is Conserved!

But its quality changes.

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The second law of thermodynamics summarizes our experience with spontaneous happenings:

All kinds of energy spontaneously spread out from where they are localized to where they are more dispersed, if they're not hindered from doing so.

The opposite does not occur spontaneously -- you don't see:

- rocks concentrating energy from all the other rocks around them and jumping up in the air, while the ground where they were cools down a little

- pans in a cupboard getting red hot by taking energy from the other pans or from the air or the cupboard.

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http://www.2ndlaw.com/entropy.html

Entropy:

A way to measure the energy that disperses or spreads out in a process (at a specific temperature).

Entropy change, delta S, measures how much energy is dispersed in a system, or how widely spread out the energy of a system becomes (at a given temperature).

Example: melting ice to water at 273 K (= 0C),

where delta S = q(rev)/T
In that equation, q (the enthalpy of fusion) is how much "heat" energy was spread out in the ice to change it to water.
[rev=reversible]

A negative delta S (a decrease in entropy) is *not* spontaneous.

http://www.2ndlaw.com/entropy.html

Photosynthesis

$$6CO_2 + 6H_2O + \underset{\text{solar}}{\text{energy}} \rightarrow \underset{\text{“sugar”}}{C_6H_{12}O_6} + 6O_2$$

How are these laws of thermodynamics related to environmental biology?

Energy
Electromagnetic Spectrum

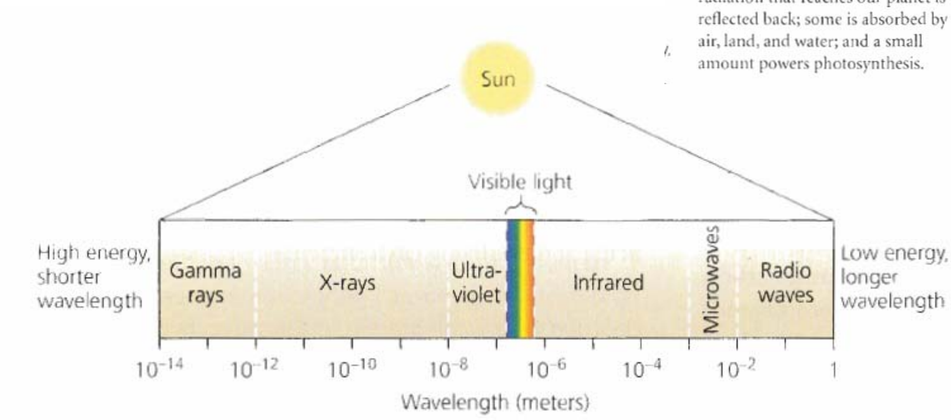

FIGURE 3.9 The sun emits radiation from many portions of the electromagnetic spectrum, and visible light makes up only a small proportion of this energy. Some radiation that reaches our planet is reflected back; some is absorbed by air, land, and water; and a small amount powers photosynthesis.

Withgott&Brennan (2007) 9

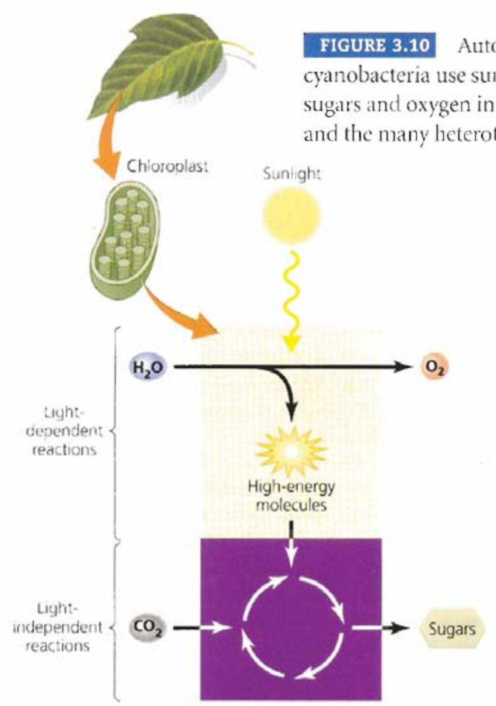

FIGURE 3.10 Autotrophs including plants, algae, and cyanobacteria use sunlight to convert carbon dioxide and water into sugars and oxygen in photosynthesis. Autotrophs provide themselves and the many heterotrophs that eat them with energy for life.

Photosynthesis

- Light Rxns

- "Dark" Rxns

Withgott&Brennan (2007) 10

Photosynthesis

$$6CO_2 + 6H_2O + \overset{\text{solar}}{\text{energy}} \rightarrow \overset{\text{"sugar"}}{C_6H_{12}O_6} + 6O_2$$

2/3 [2nd Law of Thermodynamics]

Cellular Respiration

$$\underset{\substack{\text{"sugar"} \\ \text{(glucose)}}}{C_6H_{12}O_6} + 6O_2 \rightarrow 6CO_2 + 6H_2O + \underset{\text{(ATP)}}{\text{energy}}$$

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~1%

Resources

How do we power our societies?

Petroleum

Most geologists view crude oil and natural gas as the product of compression and heating of ancient organic materials over geological time. According to this theory, oil is formed from the preserved remains of prehistoric zooplankton and algae which have been settled to the sea bottom in large quantities under anoxic conditions. (Terrestrial plants tend to form coal) Over geological time this organic matter, mixed with mud, is buried under heavy layers of sediment. The resulting high levels of heat and pressure cause the remains to metamorphose, first into a waxy material known as kerogen which is found in various oil shales around the world, and then with more heat into liquid and gaseous hydrocarbons in a process known as catagenesis. Because most hydrocarbons are lighter than rock or water, these sometimes migrate upward through adjacent rock layers until they become trapped beneath impermeable rocks, within porous rocks called reservoirs. Concentration of hydrocarbons in a trap forms an oil field, from which the liquid can be extracted by drilling and pumping. Geologists often refer to an "oil window" which is the temperature range that oil forms in—below the minimum temperature oil remains trapped in the form of kerogen, and above the maximum temperature the oil is converted to natural gas through the process of thermal cracking. Though this happens at different depths in different locations around the world, a 'typical' depth for the oil window might be 4–6 km. Note that even if oil is formed at extreme depths, it may be trapped at much shallower depths, even if it is not formed there. (In the case of the Athabasca Oil Sands, at the surface.) Three conditions must be present for oil reservoirs to form: first, a source rock rich in organic material buried deep enough for subterranean heat to cook it into oil; second, a porous and permeable reservoir rock for it to accumulate in; and last a cap rock (seal) that prevents it from escaping to the surface.

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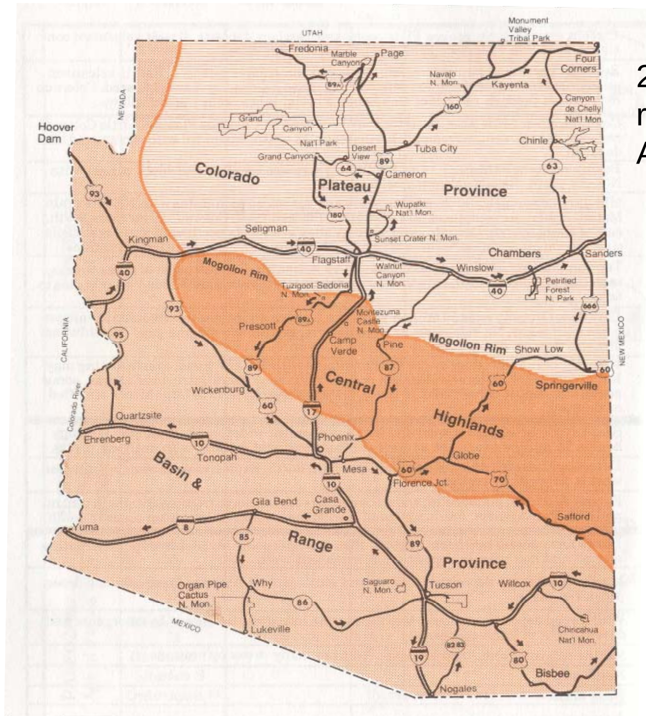
http://en.wikipedia.org/wiki/Petroleum



2 billion year old rocks visible in Arizona

Basin and Range

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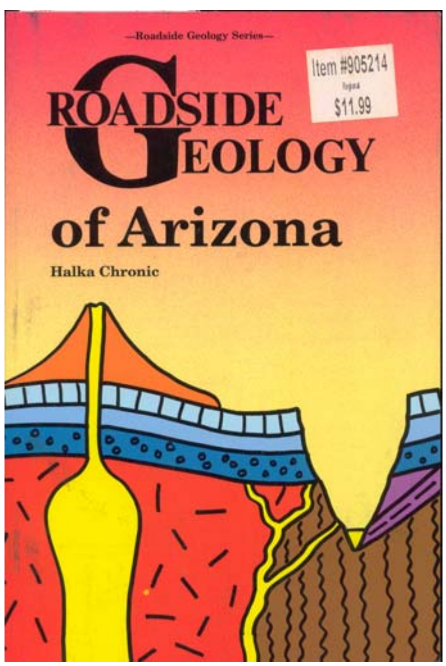

Plate Tectonics
+
<u>Erosion and Deposition</u>

"Uplift breeds down cutting"
"Basins invite deposition"

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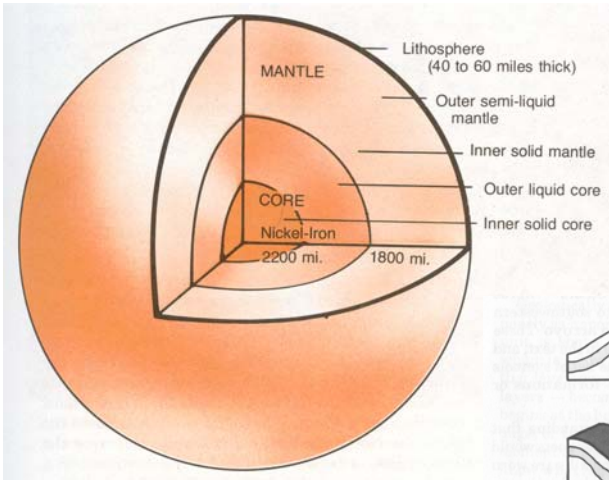
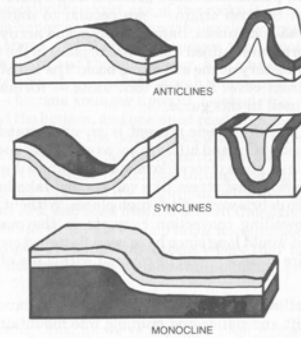


Fat on Chicken Broth?!



Three kinds of folds are easily recognized when they occur in layered (stratified) sedimentary or volcanic rocks.

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Types of Rock

Sedimentary
(Layers)

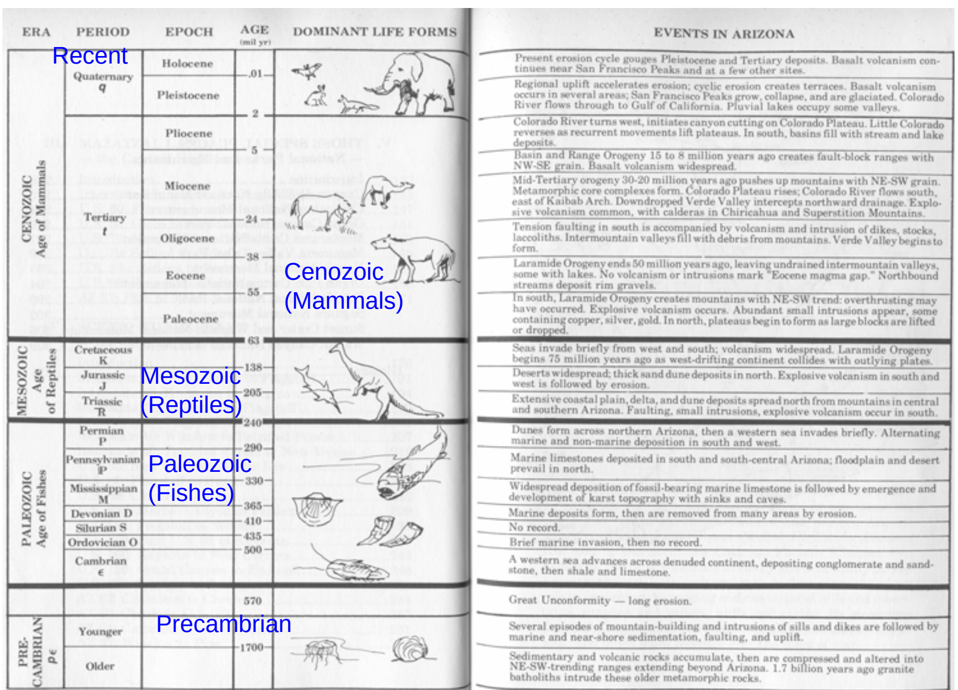
Igneous
(Extrusive Magma)

Igneous
(Intrusive Magma)

Metamorphic
(Heat and Pressure)

COMMON ROCKS OF ARIZONA

Class	Rock	Description
Sedimentary	Sandstone	Grains of sand cemented together
	Shale	Grains of silt and clay cemented together, usually breaking into flat slabs. When massive, called mudstone or siltstone.
	Conglomerate	Sand and pebbles deposited as gravel and then cemented together.
	Limestone	Composed mostly of calcite deposited as a limy mud. Usually white or gray, often containing fossils.
	Caliche	Impure limestone deposited close to the surface by groundwater evaporation.
Igneous Extrusive	Rhyolite	Light-colored, very fine-grained rock formed as lava or volcanic ash, the extrusive equivalent of granite.
	Dacite	Like rhyolite but with more alkali feldspar
	Andesite	Dark, fine-grained rock with abundant crystals of plagioclase feldspar.
	Basalt	Very fine-grained black or gray volcanic rock, often with visible gas-bubble holes or vesicles.
Igneous Intrusive	Granite	Common light-colored coarse-grained rock with visible quartz and feldspar crystals, usually peppered with black mica or hornblende.
	Monzonite	Medium-grained rock, often porphyritic, with feldspar predominating, some hornblende or quartz.
Metamorphic	Marble	Recrystalized limestone, commonly with visible calcite crystals.
	Quartzite	Sandstone and/or conglomerate so tightly cemented or welded that it breaks through individual sand grains and pebbles.
	Greenstone	Dark gray or green rock resulting from metamorphism of basalt or other dark igneous rock.
	Gneiss	Banded or streaky crystalline rock formed from older granite or sandstone.
	Schist	Medium-grained rock with mica grains lined up so that rock has streaky appearance and tends to split along parallel planes.



ERA	PERIOD	EPOCH	AGE (mil yr)
CENOZOIC Age of Mammals	Quaternary q	Holocene	.01
		Pleistocene	2
	Tertiary t	Pliocene	5
		Miocene	24
		Oligocene	38
		Eocene	55
		Paleocene	63
MESOZOIC Age of Reptiles	Cretaceous K		138
	Jurassic J		205
	Triassic R		240
PALEOZOIC Age of Fishes	Permian P		290
	Pennsylvanian P		330
	Mississippian M		365
	Devonian D		410
	Silurian S		435
	Ordovician O		500
	Cambrian є		570
PRE-CAMBRIAN pє	Younger		1700
	Older		

EVENTS IN ARIZONA

- Present erosion cycle gouges Pleistocene and Tertiary deposits. Basalt volcanism continues near San Francisco Peaks and at a few other sites.
- Regional uplift accelerates erosion; cyclic erosion creates terraces. Basalt volcanism occurs in several areas; San Francisco Peaks grow, collapse, and are glaciated. Colorado River flows through to Gulf of California. Pluvial lakes occupy some valleys.
- Colorado River turns west, initiates canyon cutting on Colorado Plateau. Little Colorado reverses as recurrent movements lift plateaus. In south, basins fill with stream and lake deposits.
- Basin and Range Orogeny 15 to 8 million years ago creates fault-block ranges with NW-SE grain. Basalt volcanism widespread.
- Mid-Tertiary orogeny 30-20 million years ago pushes up mountains with NE-SW grain. Metamorphic core complexes form. Colorado Plateau rises; Colorado River flows south, east of Kaibab Arch. Downdropped Verde Valley intercepts northward drainage. Explosive volcanism common, with calderas in Chiricahua and Superstition Mountains.
- Tension faulting in south is accompanied by volcanism and intrusion of dikes, stocks, laccoliths. Intermountain valleys fill with debris from mountains. Verde Valley begins to form.
- Laramide Orogeny ends 50 million years ago, leaving undrained intermountain valleys, some with lakes. No volcanism or intrusions mark "Eocene magma gap." Northbound streams deposit rim gravels.
- In south, Laramide Orogeny creates mountains with NE-SW trend: overthrusting may have occurred. Explosive volcanism occurs. Abundant small intrusions appear, some containing copper, silver, gold. In north, plateaus begin to form as large blocks are lifted or dropped.
- Seas invade briefly from west and south; volcanism widespread. Laramide Orogeny begins 75 million years ago as west-drifting continent collides with outlying plates.
- Deserts widespread; thick sand dune deposits in north. Explosive volcanism in south and west is followed by erosion.
- Extensive coastal plain, delta, and dune deposits spread north from mountains in central and southern Arizona. Faulting, small intrusions, explosive volcanism occur in south.
- Dunes form across northern Arizona, then a western sea invades briefly. Alternating marine and non-marine deposition in south and west.
- Marine limestones deposited in south and south-central Arizona; floodplain and desert prevail in north.
- Widespread deposition of fossil-bearing marine limestone is followed by emergence and development of karst topography with sinks and caves.
- Marine deposits form, then are removed from many areas by erosion.
- No record.
- Brief marine invasion, then no record.
- A western sea advances across denuded continent, depositing conglomerate and sandstone, then shale and limestone.
- Great Unconformity — long erosion.
- Several episodes of mountain-building and intrusions of sills and dikes are followed by marine and near-shore sedimentation, faulting, and uplift.
- Sedimentary and volcanic rocks accumulate, then are compressed and altered into NE-SW-trending ranges extending beyond Arizona. 1.7 billion years ago granite batholiths intrude these older metamorphic rocks.

Earth is 4.5 billion years old

Distribution of Organisms

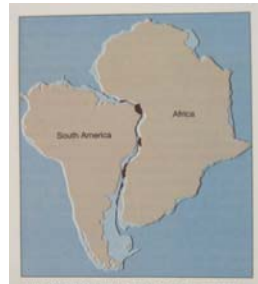


Figure 19.3 This shows the best fit of South America and Africa along the continental slope at a depth of 500 fathoms (about 900 meters). The areas where continental blocks overlap appear in brown. (After A. G. Smith, "Continental Drift." In *Understanding the Earth*, edited by I. G. Gass. Courtesy of Artemis Press)

a. Physiological Tolerances
- Temperature
- Precipitation

b. Survival and Reproduction
- Natural Selection
- Adaptation

c. Dispersal Ability
- amphibs rarely cross saltwater barriers

d. Historical Accident (including vicariance events)

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Terrestrial Biomes

(Forest, Desert, Grassland, Tundra, etc.)
Biotic (~Vegetative) Communities

Climate
1. Temperature
2. Precipitation
(3. Soil type)

- Latitude
- Altitude

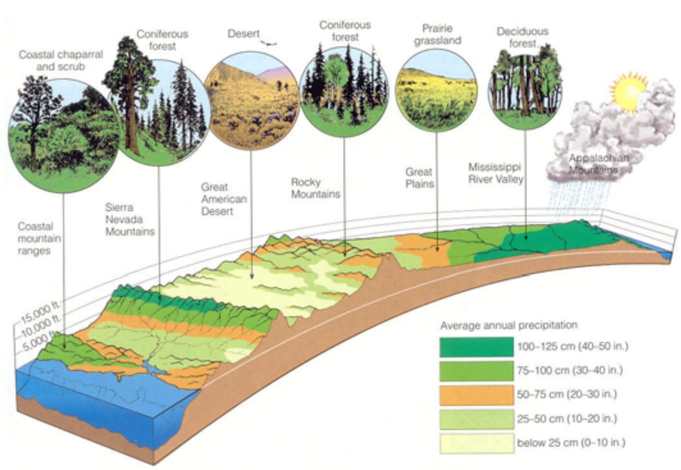
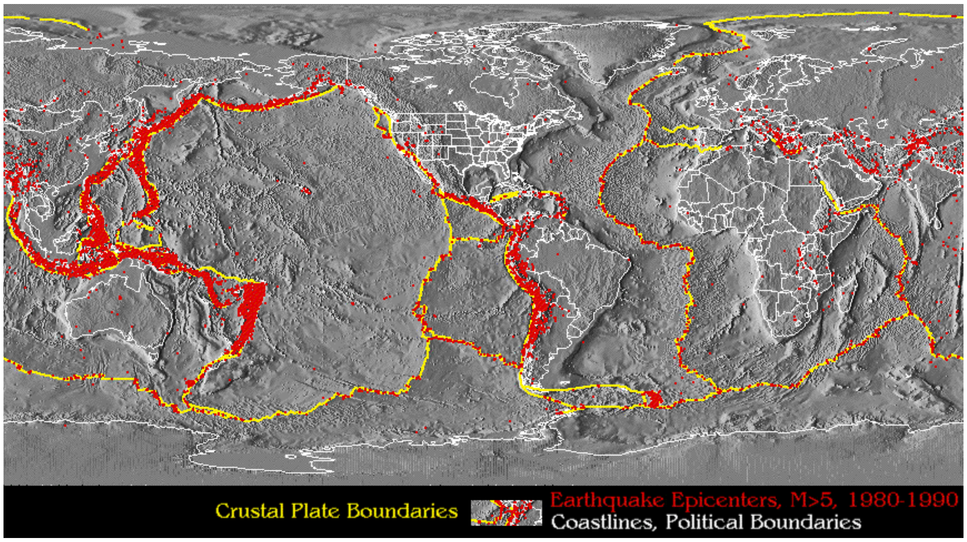


Figure 4-9 Major biomes found along the 39th parallel across the United States. The differences reflect changes in climate, mainly differences in average annual precipitation and temperature (not shown).

Miller 2003 3-5

Plate Tectonics



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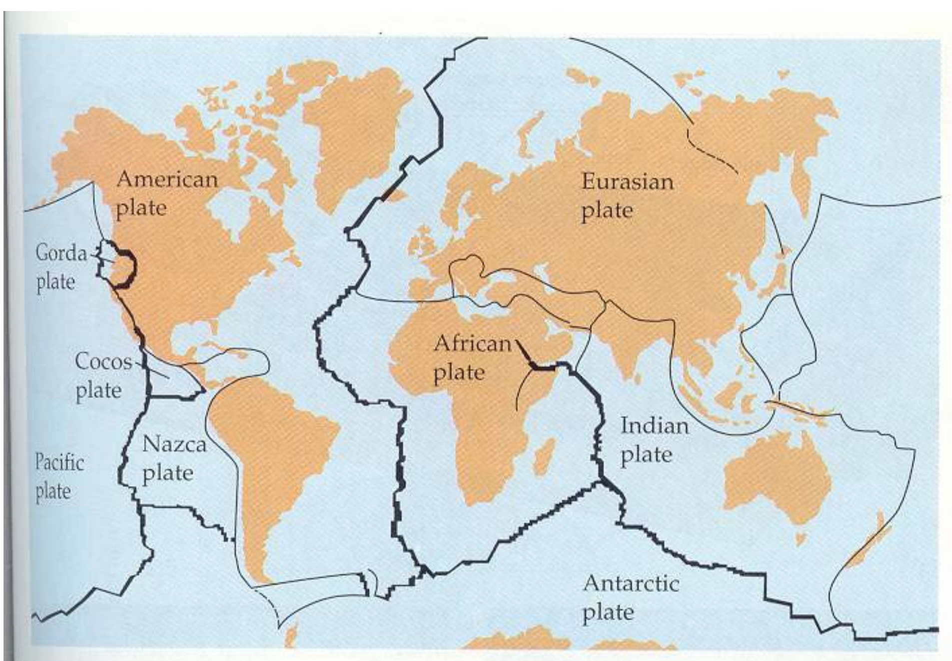

Campbell 1993

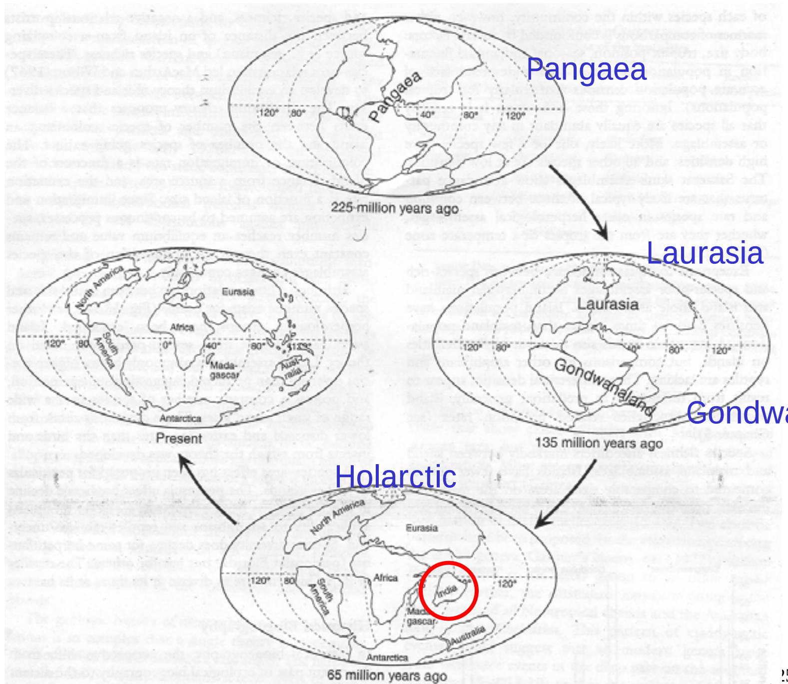

FIGURE 13.16 Diagrammatic reconstruction of the history of continental drift.

Zug et al. 2001

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Alfred Wegener,
winter 1912-1913

Crustal Plates moving
1-12 cm / year

1929 - Holmes, Magma Convection

1960s - Harry Hess (1962) and R.Deitz (1961)

Theory of Plate Tectonics

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"Scientists still do not appear to understand sufficiently that all earth sciences must contribute evidence toward unveiling the state of our planet in earlier times, and that the truth of the matter can only be reached by combing all this evidence. . . It is only by combing the information furnished by all the earth sciences that we can hope to determine 'truth' here, that is to say, to find the picture that sets out all the known facts in the best arrangement and that therefore has the highest degree of probability. Further, we have to be prepared always for the possibility that each new discovery, no matter what science furnishes it, may modify the conclusions we draw."

Alfred Wegener. *The Origins of Continents and Oceans* (4th edition)

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