

# Habitable Worlds

- Darth Vader forces Princess Leia to witness the destruction of her home planet of Alderaan.



- If forced to find a new planet for your people to live on – what would you look for.

List the 3 most important **abiotic**  
requirements for life

# Living Things Require:

1. Liquid Water
2. Raw Materials
  - (note: living things are made mostly of CHNOPS)
3. An Energy Source

# Matter and Energy



# Life

# Energy Sources for Life

- Solar
- Chemical
  - Organic molecules (carbon based (has C and H))
  - Inorganic molecules (Ex: forms of sulfur and iron  
→ redox reactions → energy for some bacteria))

# Liquid Water

- Dissolves and moves things
- Helps maintain balances (homeostasis)
  - Balances temperature
  - Balances concentrations of dissolved things

# Raw materials = Nutrients

- Living things are made up of CHNOPS = 6 most important elements of life
- *What do you know about CHNOPS????*

# Nutrients must be recycled

- Decomposers recycle nutrients
- **ROCK CYCLE AND PLATE TECTONICS**  
**IMPORTANT** – Earth = only planet with  
plate tectonics



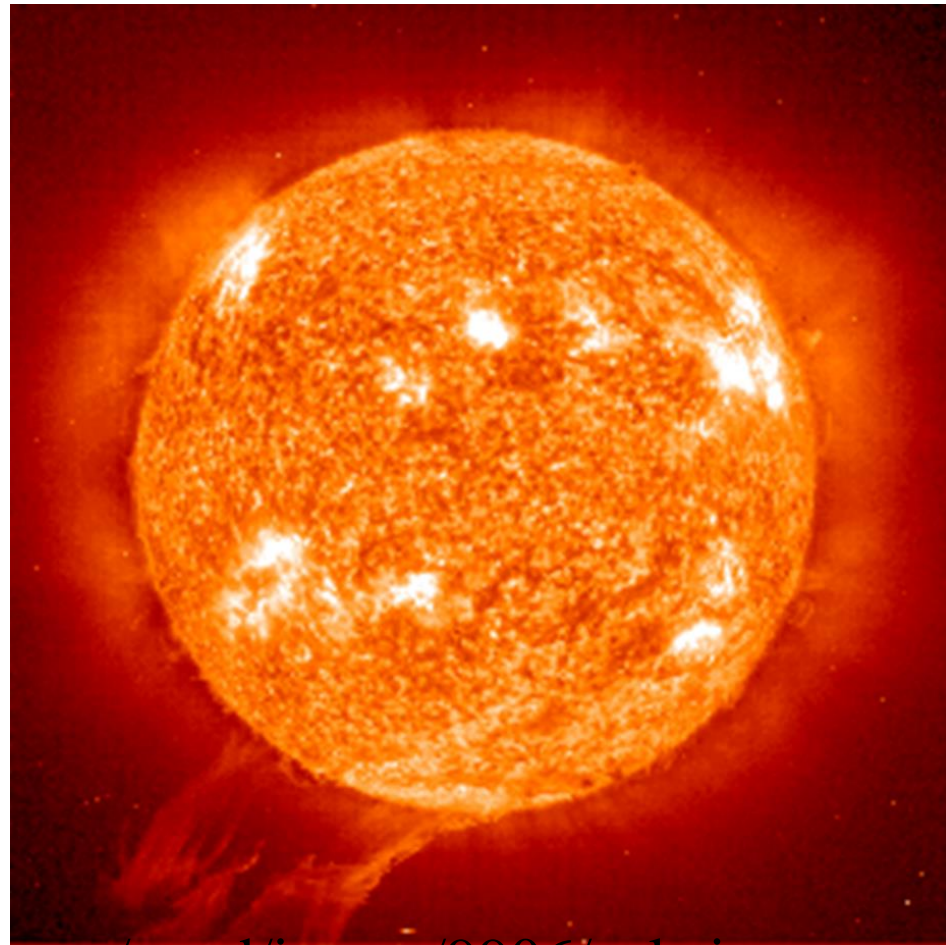
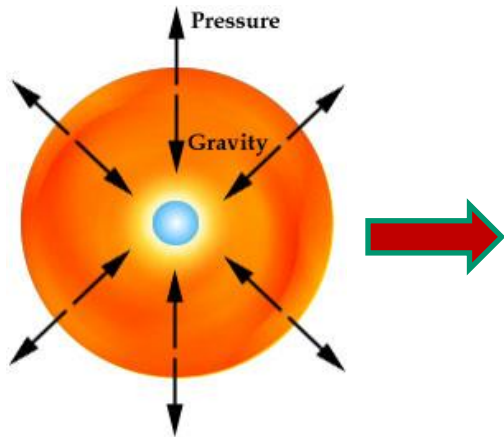
# Origins of the Earth

origins  
EARTH IS BORN

The world as we know it starts as  
a large cloud of gas and dust



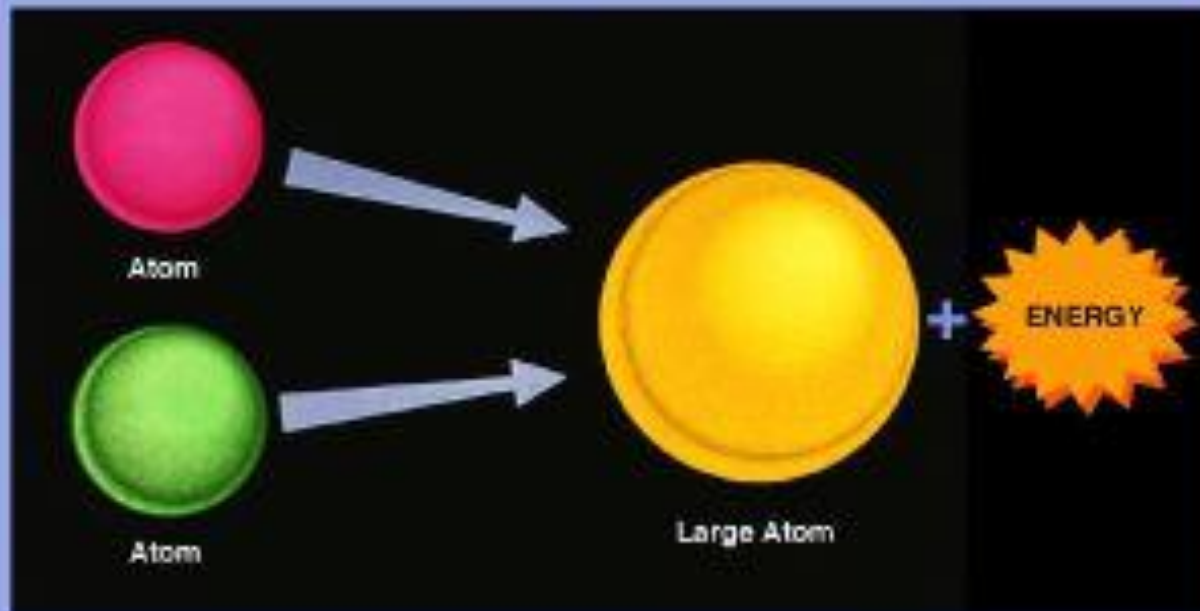
A star is born when gravity pulls molecules so close they begin to fuse

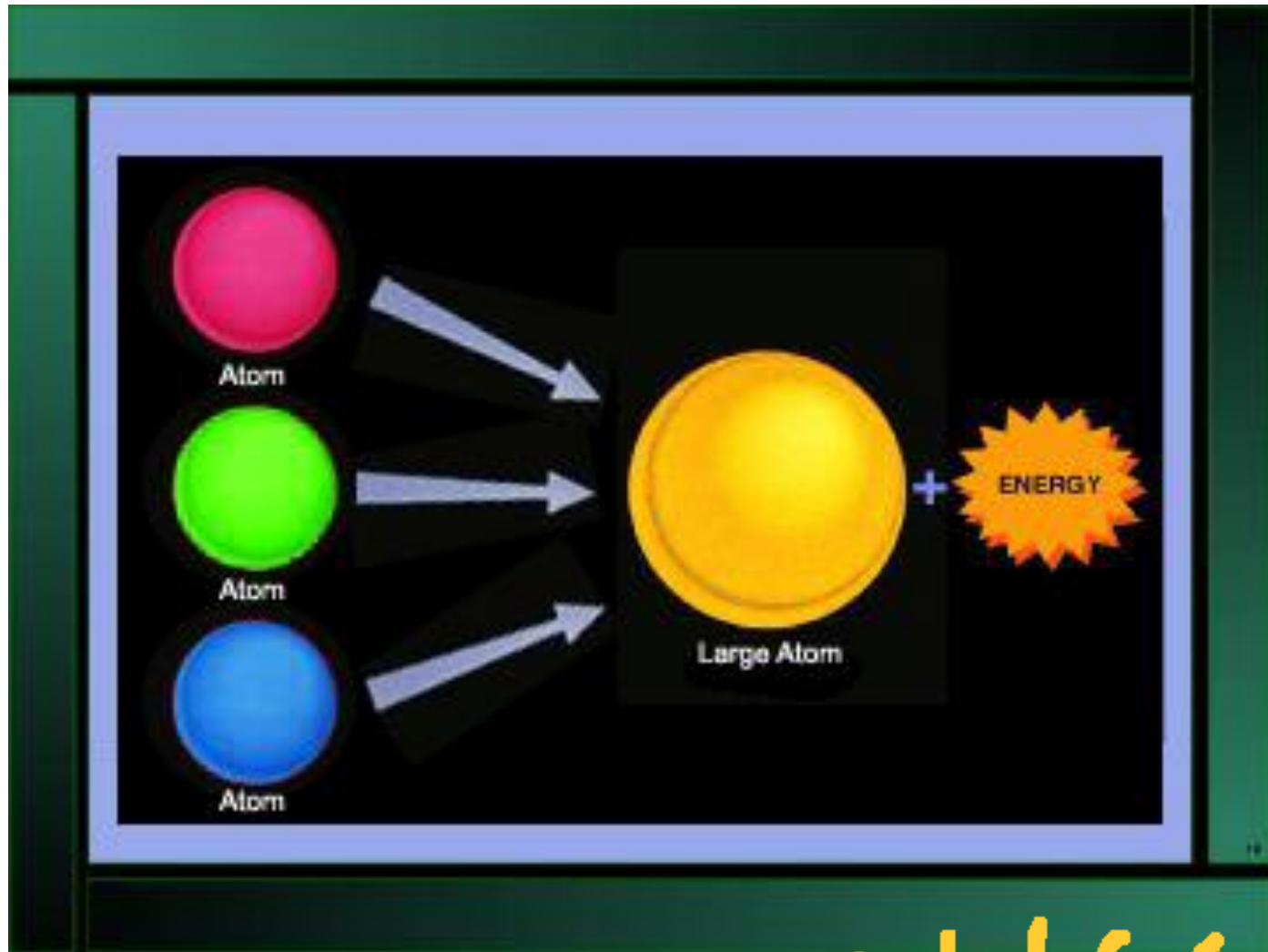


[http://antwrp.gsfc.nasa.gov/apod/image/9906/solstice\\_erupt\\_big.gif](http://antwrp.gsfc.nasa.gov/apod/image/9906/solstice_erupt_big.gif)

Define fusion

## Fusion



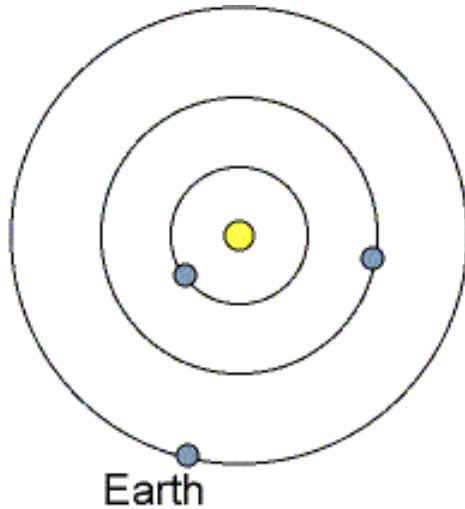




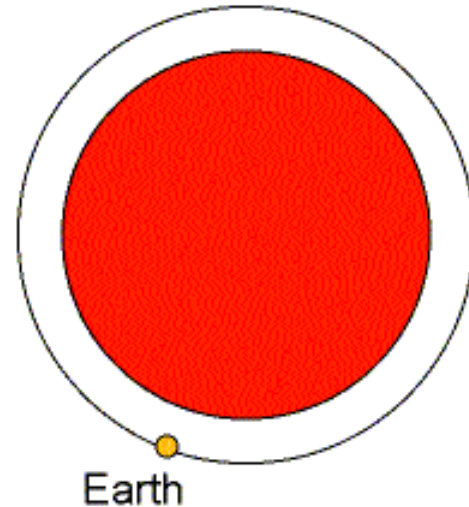
# Fusion reactions within stars → all of the elements up to iron

|                   |    |      |     |     |     |      |      |     |     |     |     |      |     |     |     |      |      |
|-------------------|----|------|-----|-----|-----|------|------|-----|-----|-----|-----|------|-----|-----|-----|------|------|
| Group IA          |    |      |     |     |     |      |      |     |     |     |     | VIII |     |     |     |      |      |
| 1                 |    |      |     |     |     |      |      |     |     |     |     | 2    |     |     |     |      |      |
| H                 |    |      |     |     |     |      |      |     |     |     |     | He   |     |     |     |      |      |
| IIA               |    |      |     |     |     |      |      |     |     |     |     | III  | IV  | V   | VI  | VII  | VIII |
| 3                 | 4  |      |     |     |     |      |      |     |     |     |     | 5    | 6   | 7   | 8   | 9    | 10   |
| Li                | Be |      |     |     |     |      |      |     |     |     |     | B    | C   | N   | O   | F    | Ne   |
| IIIA              |    | IIIA | IVA | VA  | VIA | VIIA | VIII |     | IB  | II  | III | IV   | V   | VI  | VII | VIII |      |
| 11                | 12 | 13   | 14  | 15  | 16  | 17   | 18   | 19  | 20  | 21  | 22  | 23   | 24  | 25  | 26  | 27   |      |
| Na                | Mg | Al   | Si  | P   | S   | Cl   | Ar   | K   | Ca  | Sc  | Ti  | V    | Cr  | Mn  | Fe  | Co   |      |
| 19                | 20 | 21   | 22  | 23  | 24  | 25   | 26   | 27  | 28  | 29  | 30  | 31   | 32  | 33  | 34  | 35   |      |
| K                 | Ca | Sc   | Ti  | V   | Cr  | Mn   | Fe   | Co  | Ni  | Cu  | Zn  | Ga   | Ge  | As  | Se  | Br   |      |
| 37                | 38 | 39   | 40  | 41  | 42  | 43   | 44   | 45  | 46  | 47  | 48  | 49   | 50  | 51  | 52  | 53   |      |
| Rb                | Sr | Y    | Zr  | Nb  | Mo  | Tc   | Ru   | Rh  | Pd  | Ag  | Cd  | In   | Sn  | Sb  | Te  | I    |      |
| 55                | 56 | 71   | 72  | 73  | 74  | 75   | 76   | 77  | 78  | 79  | 80  | 81   | 82  | 83  | 84  | 85   |      |
| Cs                | Ba | Lu   | Hf  | Ta  | W   | Re   | Os   | Ir  | Pt  | Au  | Hg  | Tl   | Pb  | Bi  | Po  | At   |      |
| 87                | 88 | 103  | 104 | 105 | 106 | 107  | 108  | 109 | 110 | 111 | 112 | 81   | 82  | 83  | 84  | 85   |      |
| Fr                | Ra | Lr   | Unq | Unp | Unh | Uns  | Uno  | Une | Uun | Uuu | Uub | Tl   | Pb  | Bi  | Po  | At   |      |
| Lanthanide Series |    | 57   | 58  | 59  | 60  | 61   | 62   | 63  | 64  | 65  | 66  | 67   | 68  | 69  | 70  |      |      |
| Actinide Series   |    | 89   | 90  | 91  | 92  | 93   | 94   | 95  | 96  | 97  | 98  | 99   | 100 | 101 | 102 |      |      |
|                   |    | La   | Ce  | Pr  | Nd  | Pm   | Sm   | Eu  | Gd  | Tb  | Dy  | Ho   | Er  | Tm  | Yb  |      |      |
|                   |    | Ac   | Th  | Pa  | U   | Np   | Pu   | Am  | Cm  | Bk  | Cf  | Es   | Fm  | Md  | No  |      |      |

# Eventually stars (including our sun) will run out of fuel



Now: hot core + warm surface; small size.



Future: very hot core + cool surface. Large size but less mass; very bright.

- 6.5 billion years from now

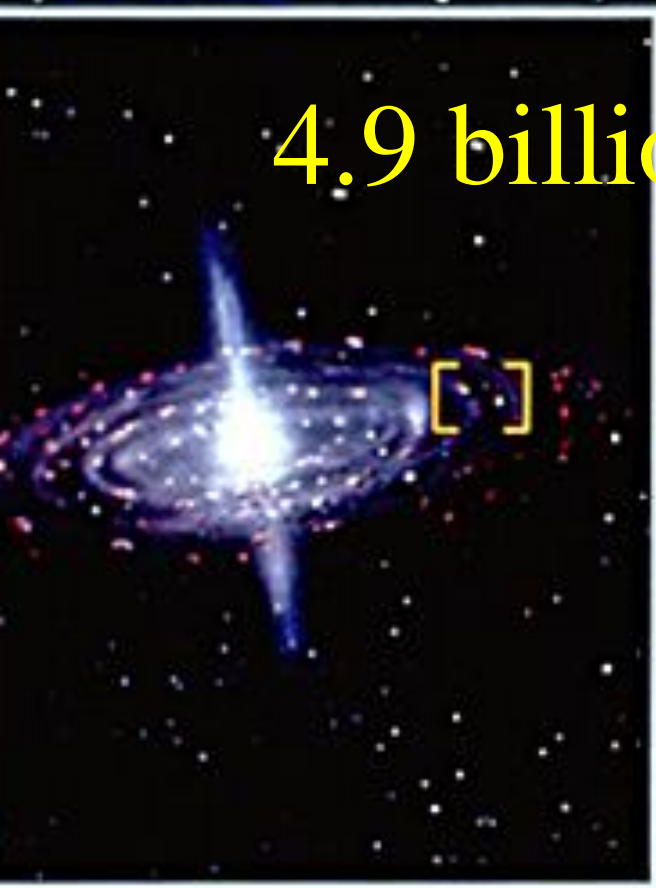


They explode with a massive amount of energy  
→ heavier elements like silver and gold



# Origin of our solar system timeline

4.9 billion years ago



PARTICLES OF DUST STICK TOGETHER...  
CLUMP IN CENTER HEATS UP...

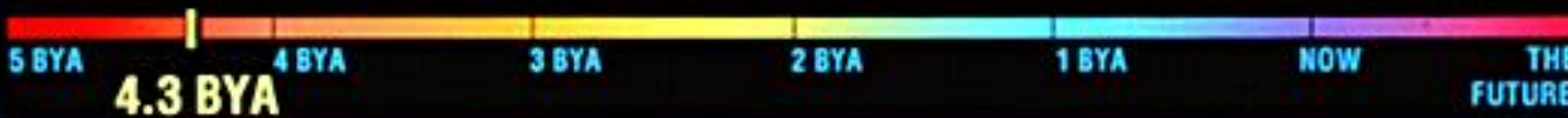
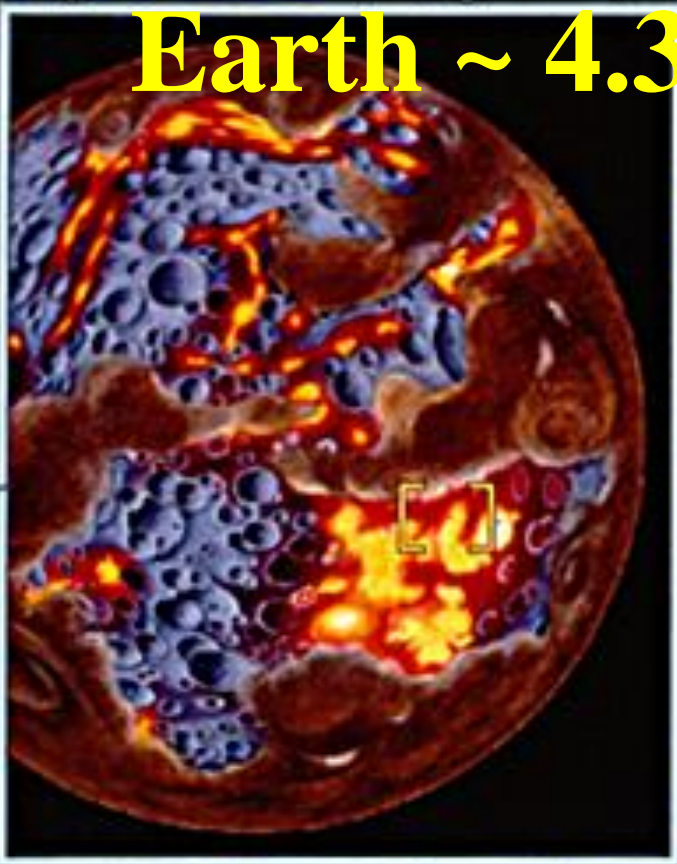
# 4.5bya Sun and Planets are Born



**GLOWING GAS IN CENTER HEATS...BECOMES SUN...  
SMALL ORBITING CLUMPS BECOME PLANETS!**

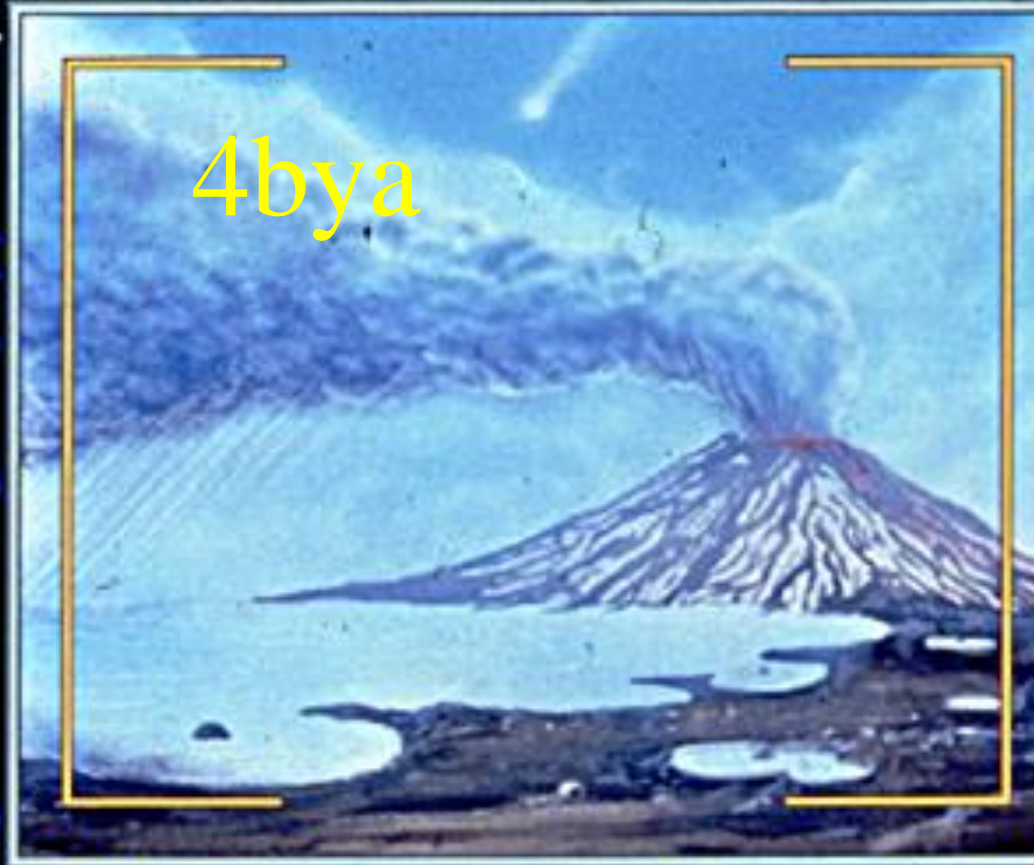
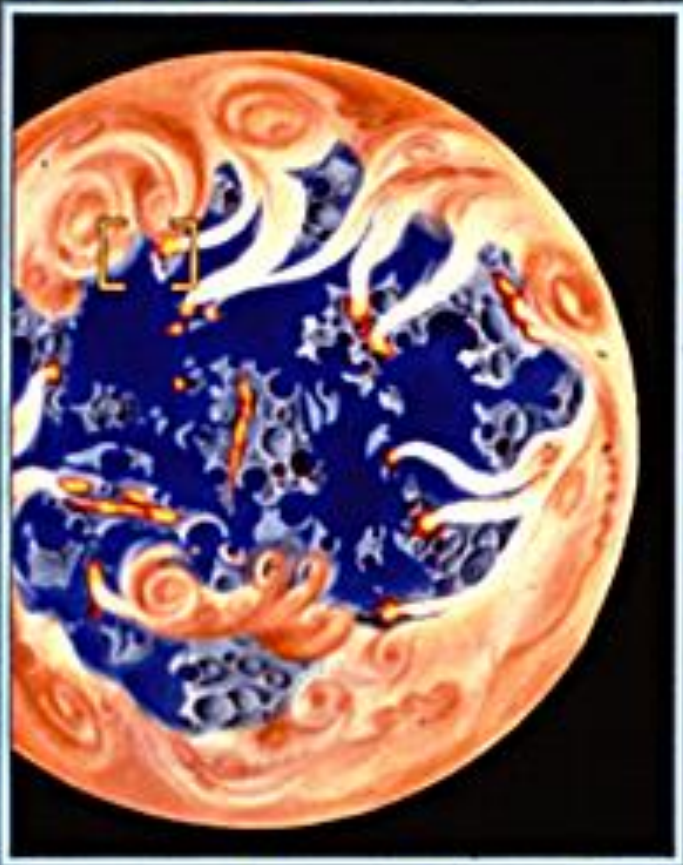


# Earth ~ 4.3 billion years old



**ASTERIODS CONTINUE TO BLAST EARTH AND MOON!  
MOLTEN SURFACE STARTS TO SOLIDIFY**





4bya

5 BYA

4.0 BYA

3 BYA

2 BYA

1 BYA

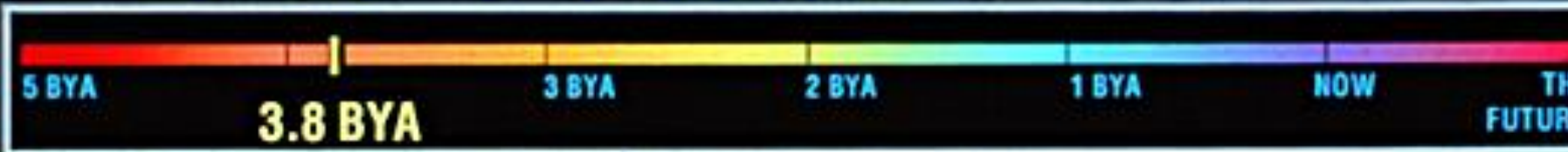
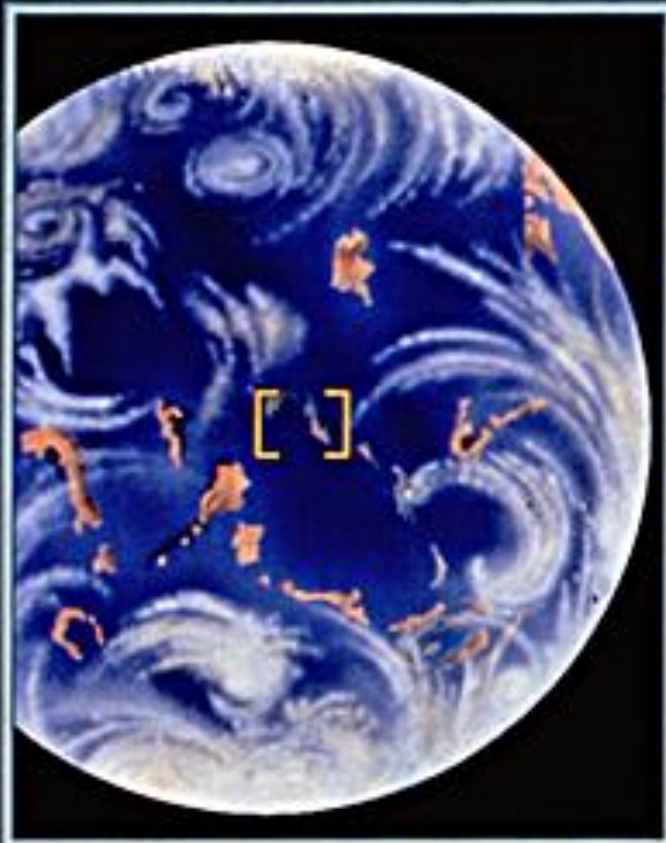
NOW

THE FUTURE

LIQUID WATER ON EARTH'S SURFACE!



# Life??? ~ 3.8 billion years ago



**ORGANIC MOLECULES + ENERGY CREATE NEW LIFE!  
HOW? WHERE? SCIENTISTS PUZZLED**



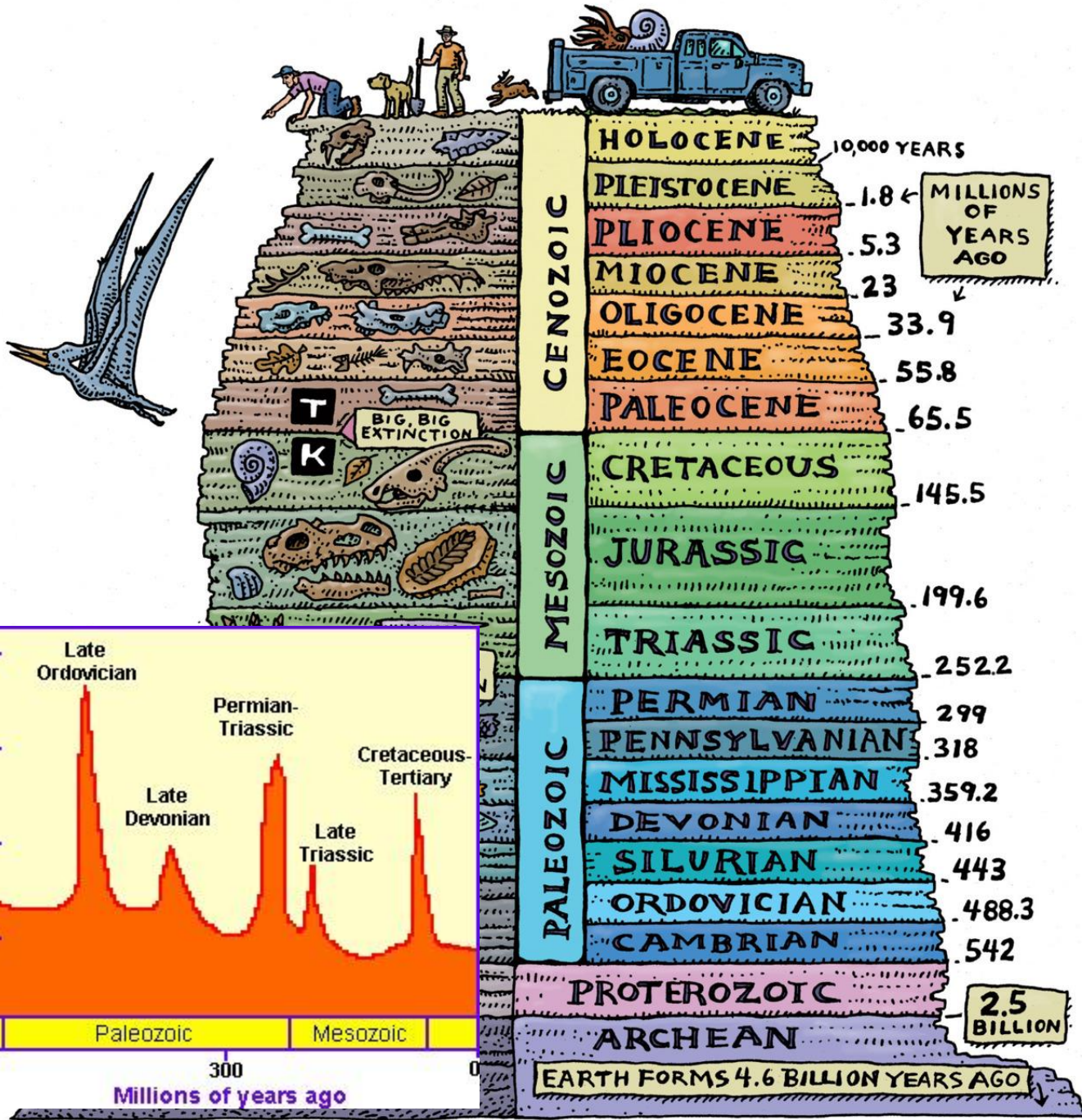
# 3.7bya fossils found in Greenland

(2016 NBC News article)



Stromatolite





# Define Evolution

# Steps of evolution

- Must have variation → different phenotypes
  - (inc by mutation and sexual reproduction)
- Competition and environmental stress → natural selection → survival of the fittest
- Best adapted survive and reproduce

# What is necessary for evolution to occur

- Sexual reproduction and mutations → variation in populations
- Change in environment
- Competition → natural selection
- Best adapted survive and reproduce

# Things that limit the ability to adapt

- Genetic drift (random changes in gene pool → good genes can be lost)
- Limited genetic variability in population
- Time delays (cannot adapt fast enough)
- Low reproductive capacity (not enough males and females, long gestation period)

# Define Extinction

- Background extinction rate - relatively constant rate of extinction in the fossil record
- Mass extinction - major loss of many species
  - climate change, catastrophic events, humans

# Former Mass Extinctions

- Fossil evidence suggest 5 mass extinctions
- Most recent mass extinction = 65mil years ago (dinosaurs)
  - Theory = caused by large asteroid falling in Yucatan Peninsula (Mexico) → massive dust clouds → global cooling
  - Supported by huge global deposits of iridium(rare on earth common on meteors) in K-T boundary clay deposits

# Current crisis

- According to Conservation International extinction rates = 1000x's higher than background
- Human activities account for most of these extinctions



# How humans increase extinction rates

1. HABITAT LOSS = #1 cause of extinction
  - Simplify ecosystems (ex: monocultures → food deserts)
2. Introducing new species (ex: emerald ashborer, purple loosestrife)
3. Direct harvest / Overhunting
4. Pollution (ex: DDT killed bald eagles, GHGs → climate change)

# Why we should care about high extinction rates

1. Diversity → stability
2. Loss of species = loss of resources

# The Dynamic Earth



# Earth's Internal Zones

- **CORE mostly iron**

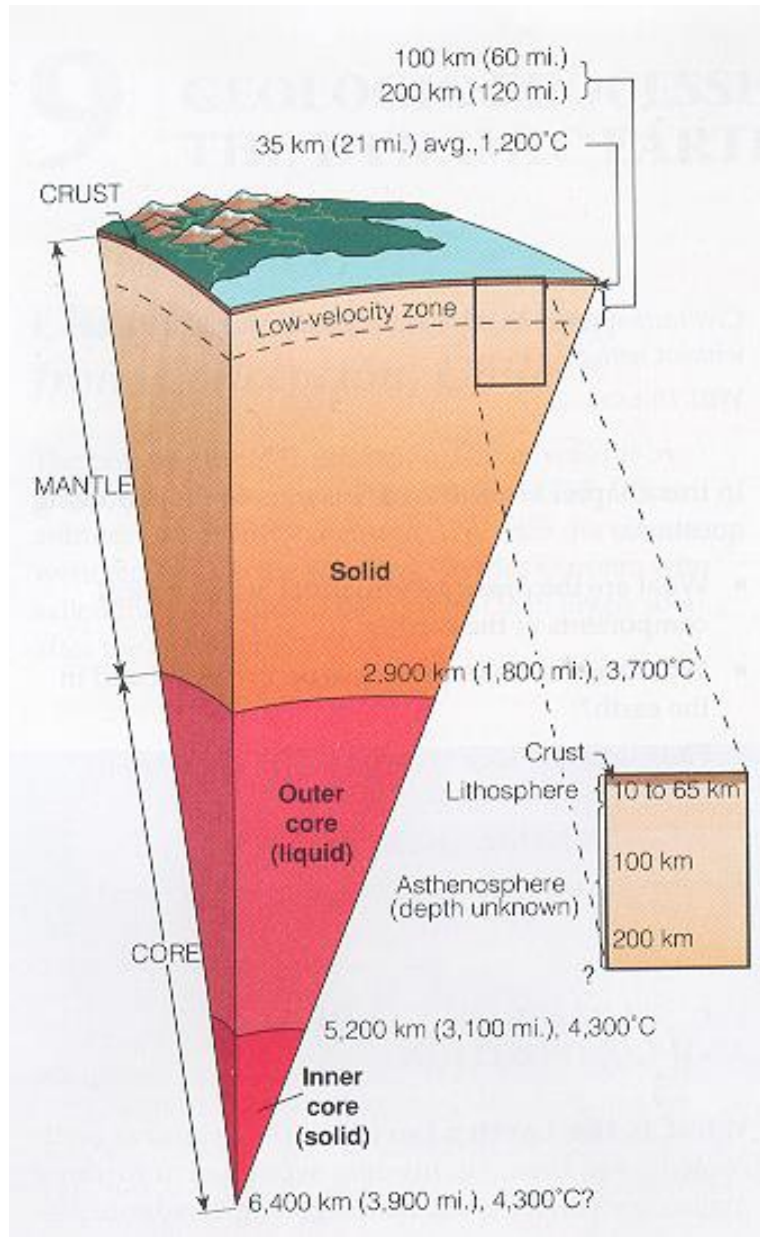
- 2 parts

- inner core – solid due to hi pressure,
- outer core – liquid due to hi temps 3700-4300C

- **MANTLE (Fe, O, Si, Mg...)**

- Mostly solid

- Asthenosphere = low velocity zone slows down seismic waves



Crust = 10 -65 km thick

1 mile = 1.6 km

How many miles thick is the crust?

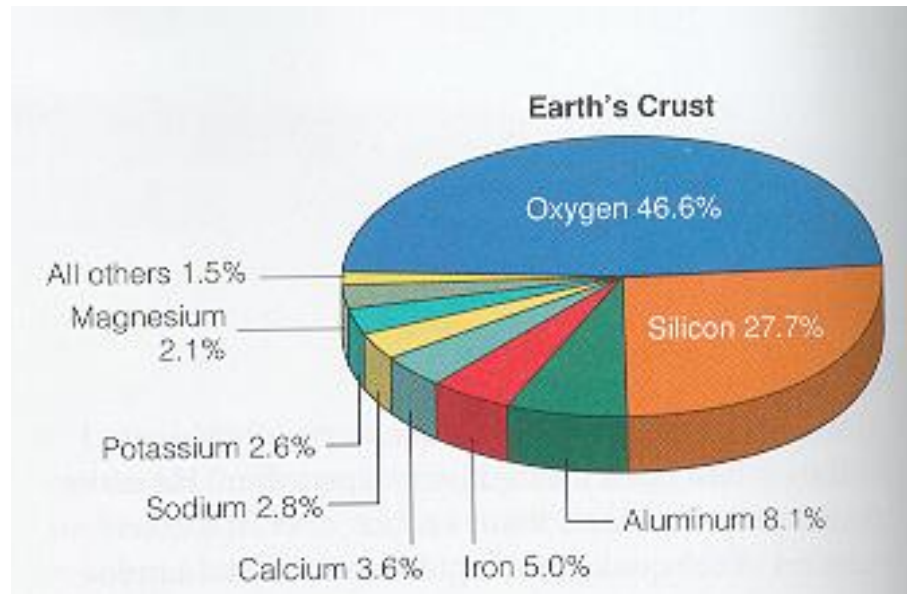
Show math – no calculators

# Answers

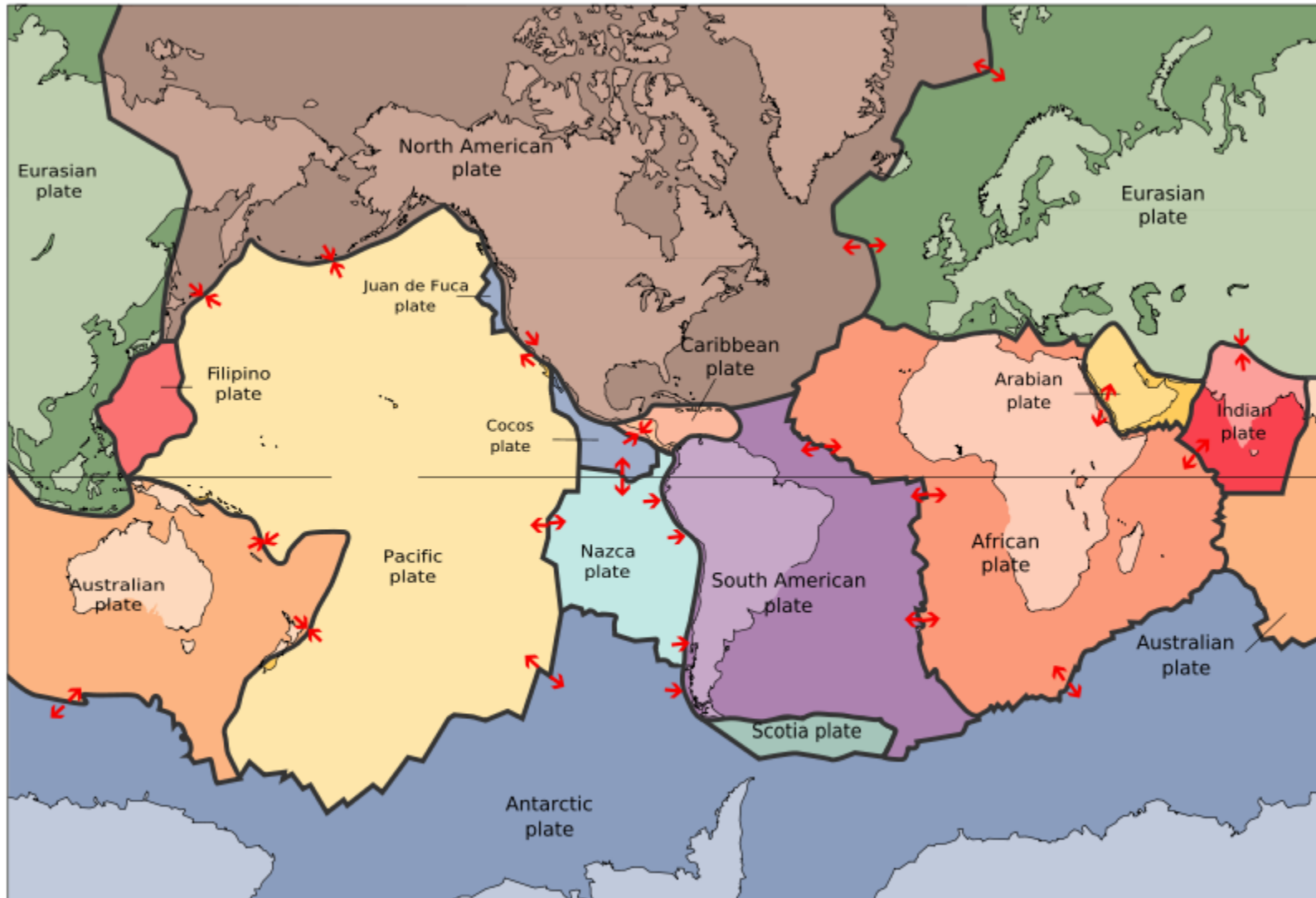
- $10 \text{ km} = 6.25 \text{ mi}$
- $65 \text{ km} = 40.625 \text{ mi}$

# Crust (10-65 km thick)

- Most abundant element in crust (most mass) = OXYGEN
- 2 types (71% surface = oceanic, remainder = continental)
- Crust and upper mantle = lithosphere



Lithosphere is divided into 20 plates that float on the asthenosphere



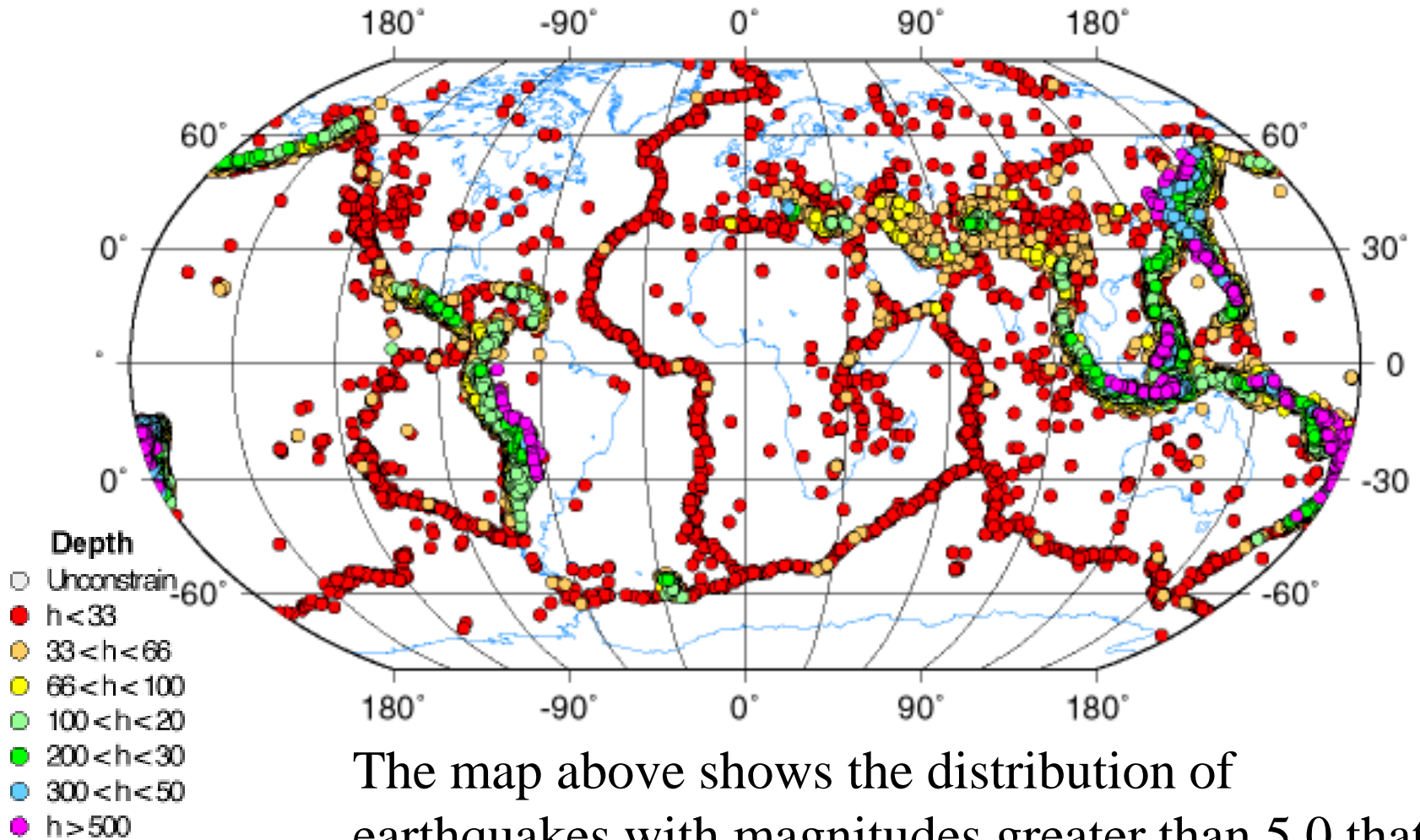


Plates move (~1 inch/year)  
what happens at boundaries????



Volcanoes

# Earthquakes occur at boundaries



The map above shows the distribution of earthquakes with magnitudes greater than 5.0 that occurred between 1965 and 1995.

# Support for plate movement

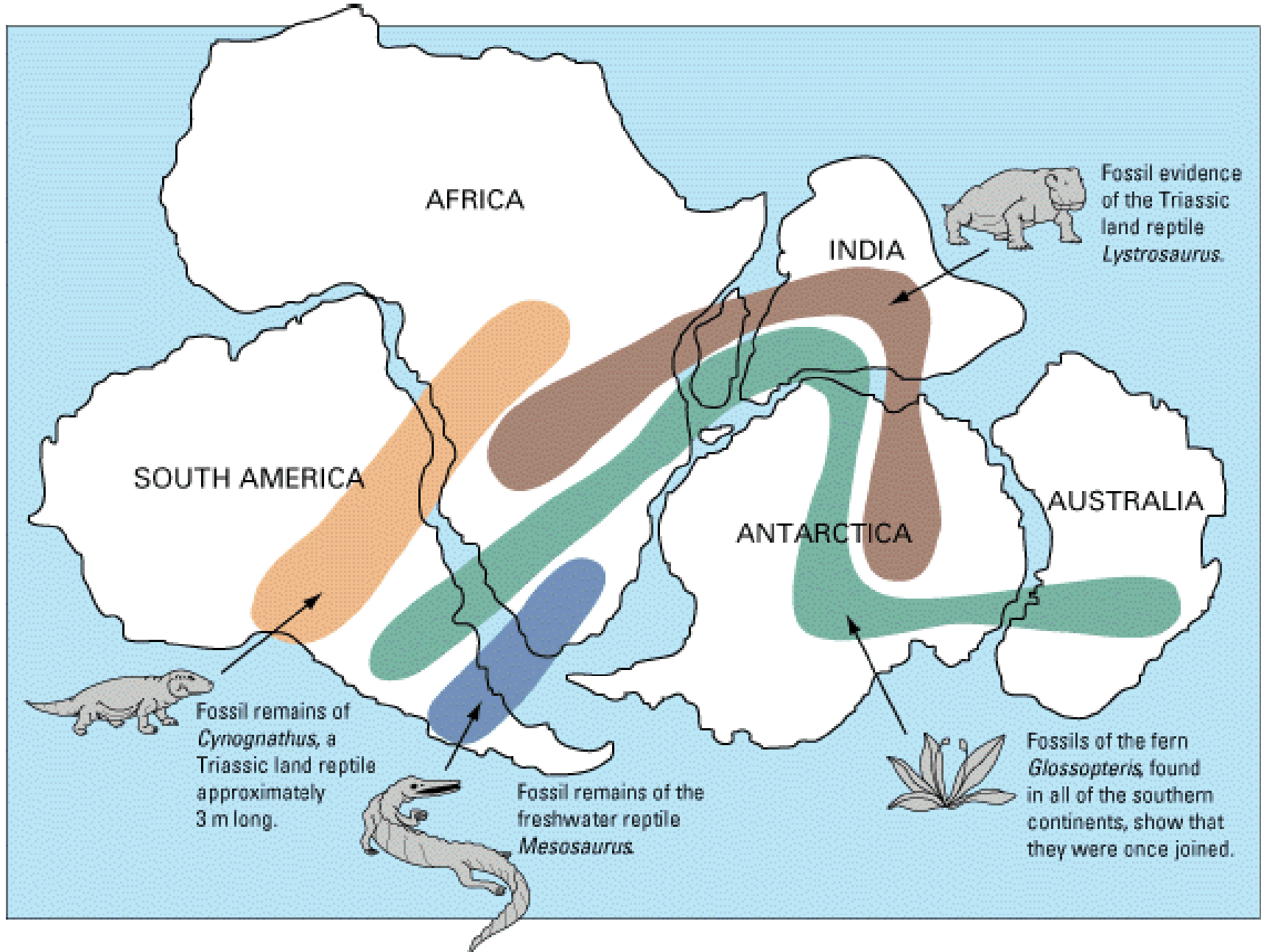
- At plate boundaries → volcanoes and earthquakes
- Plate tectonics → 3 geomorphologic features
  - (spreading centers, arc volcanoes, and subduction trenches)

# Matching Coastlines and Glacier Evidence

## Glacier Evidence



# Fossil Evidence



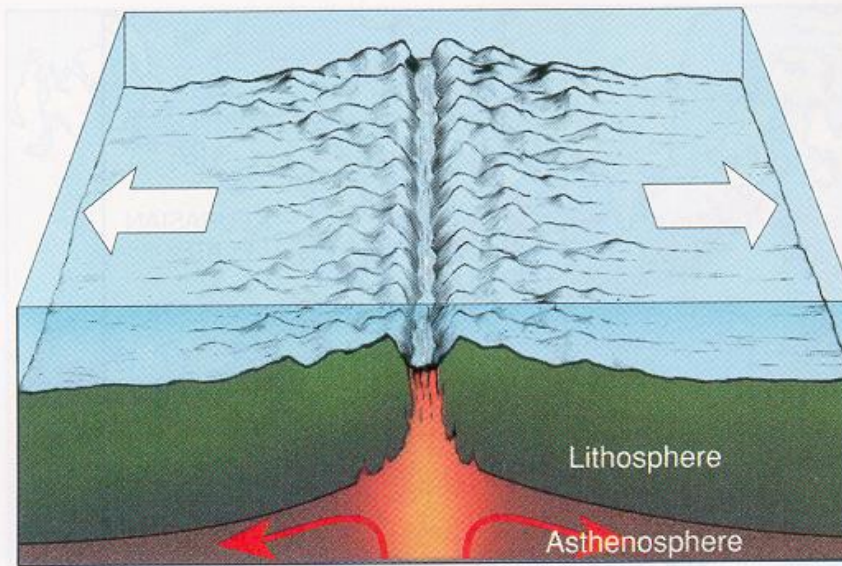
# Plate Tectonics

- The theory that describes these plates and their movement
- Earth is the only planet in the solar system with plate tectonics
- HOW do we know???
- Plate boundaries → unique features
  - (spreading centers, arc volcanoes, and subduction trenches)

# Divergent boundaries →

## Spreading Centers

- Occur where plates come apart
- → Youngest parts of the ocean

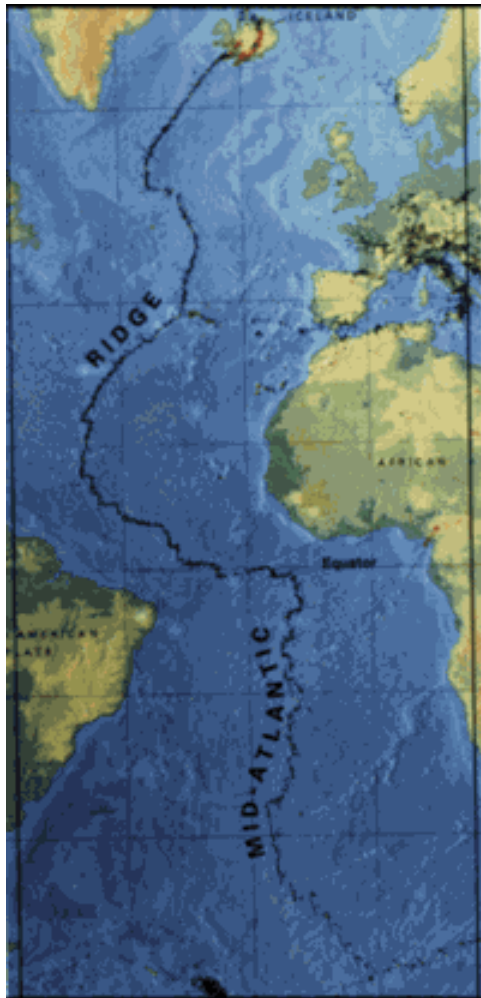


Oceanic ridge at a divergent plate boundary

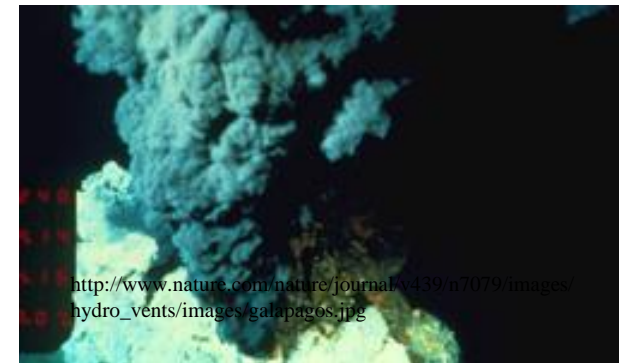
[http://www.geologie.uni-mainz.de/deutsch/gal\\_ice.htm#](http://www.geologie.uni-mainz.de/deutsch/gal_ice.htm#)



# Ex: Mid-Atlantic Ridge

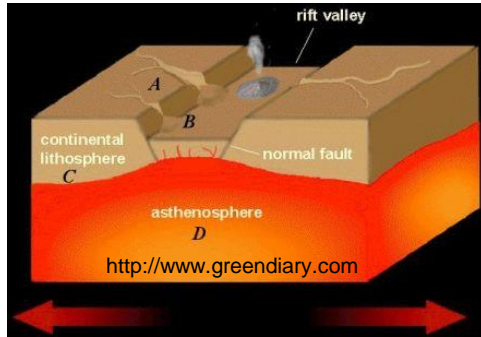


- Runs thru Iceland → lots of geothermal energy
- Volcanoes circulate hot water → hydrothermal vent communities at rift
  - *Poseidon and Mt. Atlantis*





# Ex: Africa's Great Rift Valley

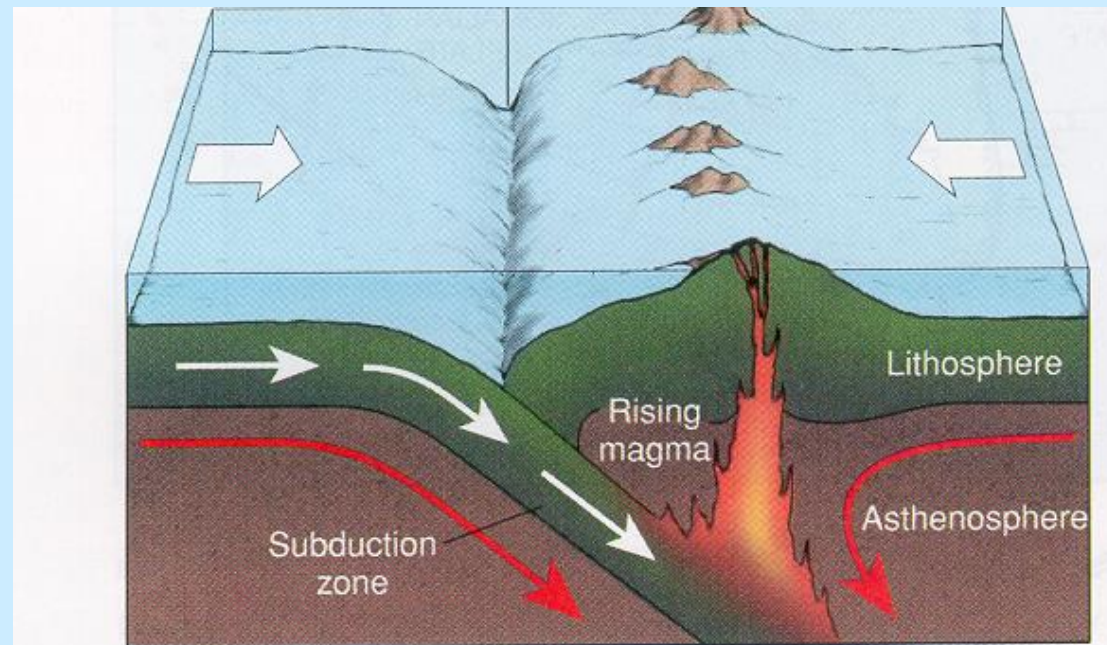


- Note Lake Victoria between the rift valleys (Tall rift mtns. → depression →)
- 2<sup>nd</sup> largest freshwater lake in world (by area) (*Lake Superior = largest*)
- Kilimanjaro formed near a spreading center



# Convergent boundaries → Subduction Zones → Arc volcanoes and trenches

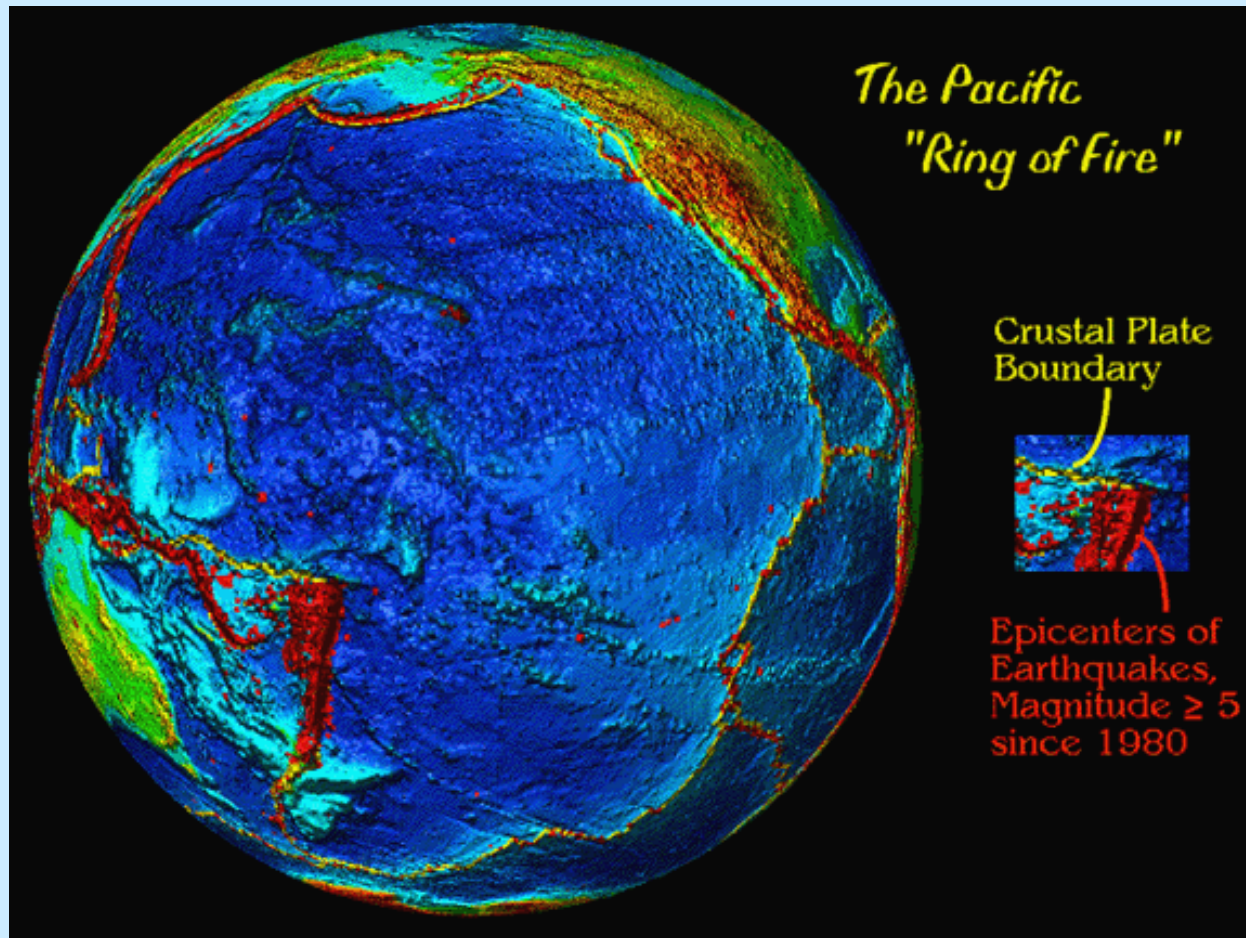
- Plates move toward each other
- Often: oceanic plate subducted under continental plate



Trench and volcanic island arc at a convergent plate boundary

Fracture zone

# Subduction → Ring of fire (most volcanically active belt on Earth)







Cleveland Volcano - Aleutian Islands - May 2006  
ISS JN Williams - NASA





# Cascades of Washington

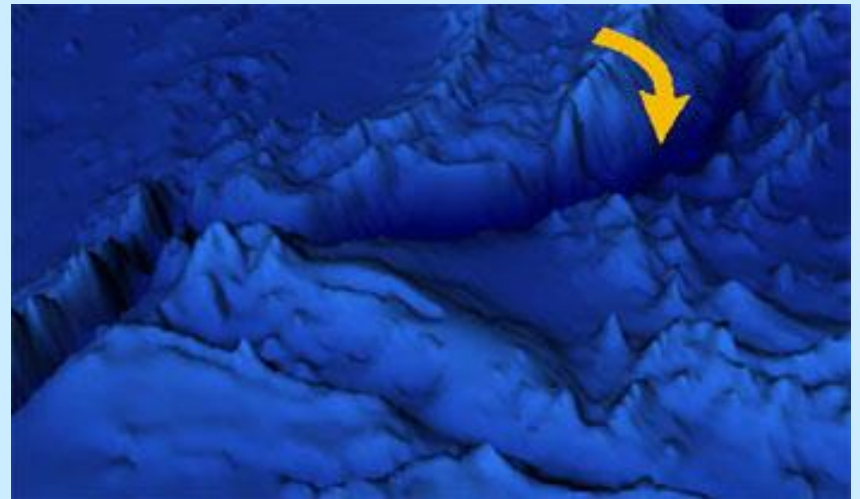


[http://www.geo.umn.edu/orgs/whitney/prospective\\_students\\_08.html](http://www.geo.umn.edu/orgs/whitney/prospective_students_08.html)

# Subduction zones → deep ocean trenches



- Mariana trench = deepest part of the ocean (~11km = ?? miles)(1mi = 1.6km)



# Different types of convergent boundaries

- Continent to continent (→ Himalayas)
- Continent to ocean (→ Andes Mountains)
- Ocean to ocean (→ arc islands (Aleutians))

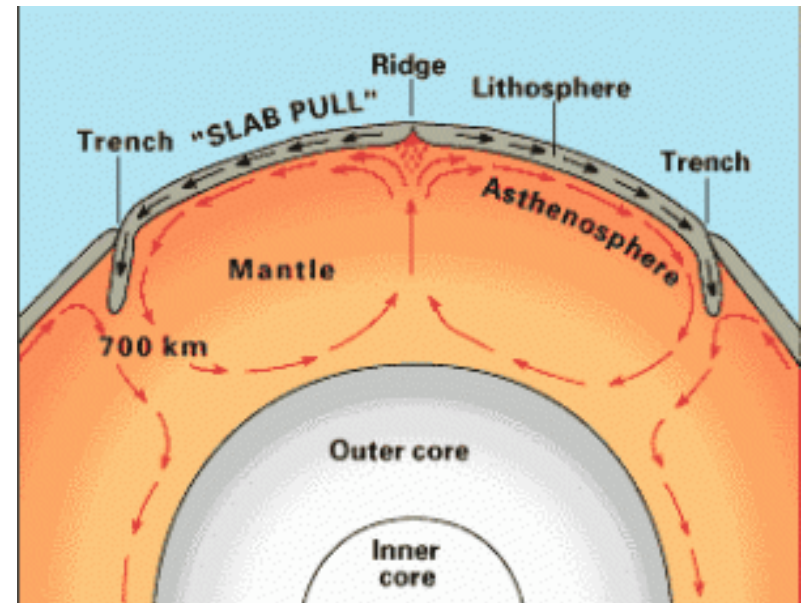
# Transform Faults

- Plates slide past each other
- Mostly earthquakes
- Ex: San Andrea Fault



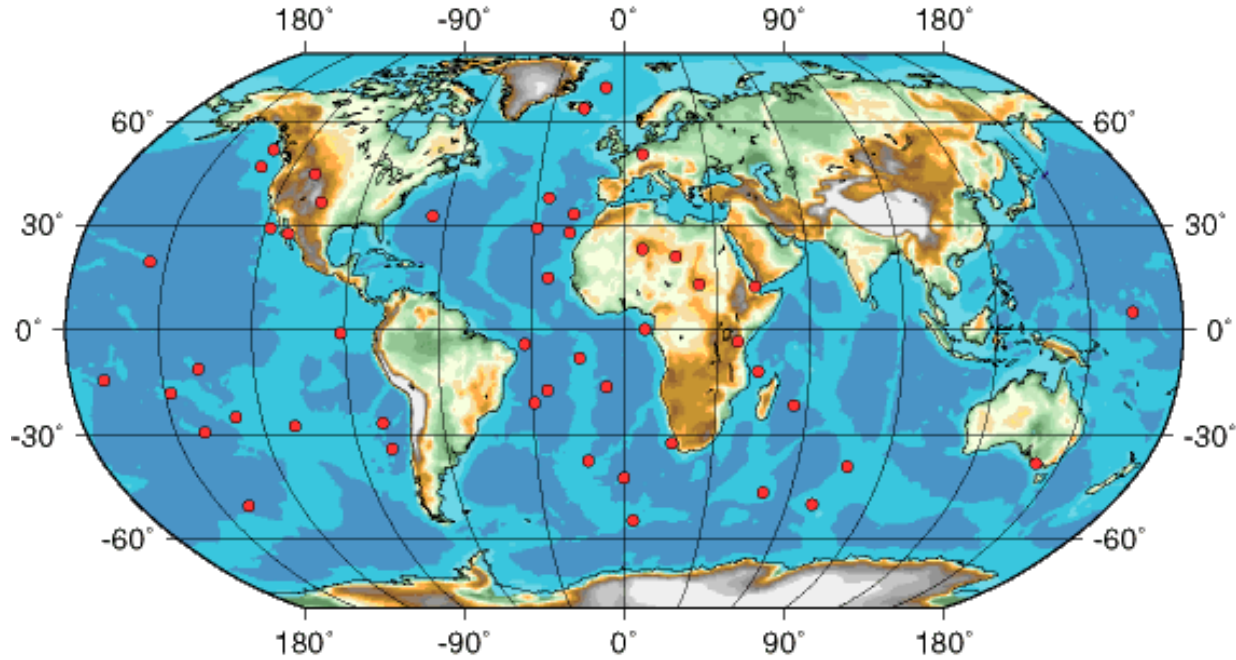
# Convection of heat in mantle → plate movement

- Define convection
- Convection = transfer of heat within a substance in currents





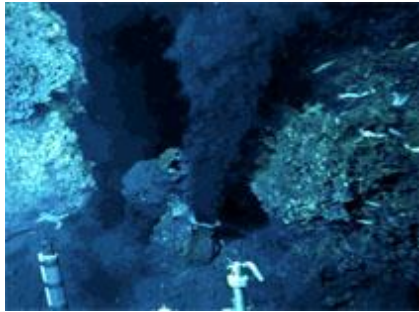
# Hot Spots



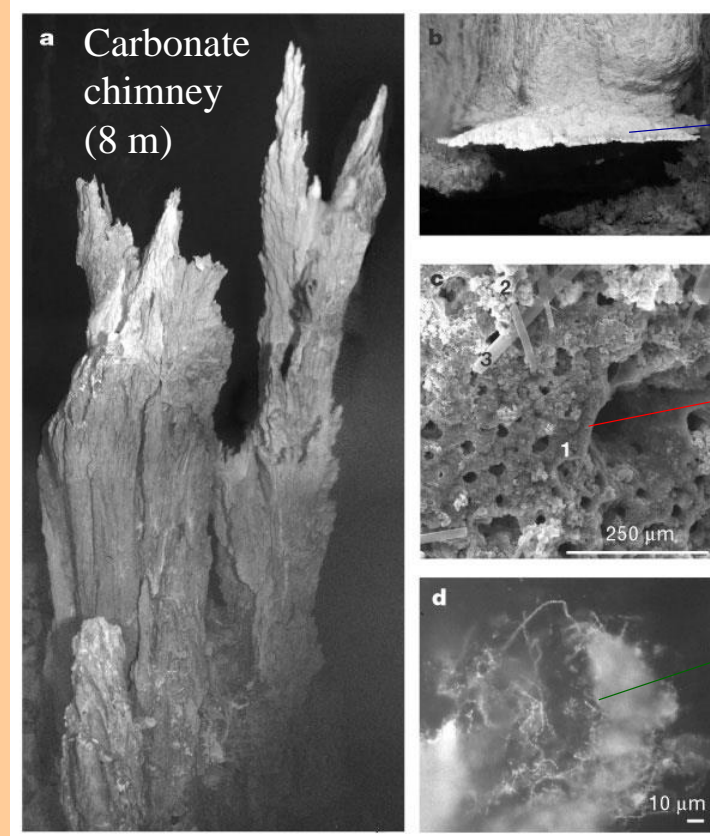
[http://eqseis.geosc.psu.edu/~cammon/HTML/Classes/IntroQuakes/Notes/plate\\_tect01.html](http://eqseis.geosc.psu.edu/~cammon/HTML/Classes/IntroQuakes/Notes/plate_tect01.html)

- Some volcanoes not associated with plate boundaries or plate movement
  - Ex: Hawaii

# Life exists in the vents near hot spots



Black smokers → sulfides, ash and energy



Off-axis vent (~60°C)

Aragonite and brucite flange

Lost City ventfield

SEM picture of 'b'

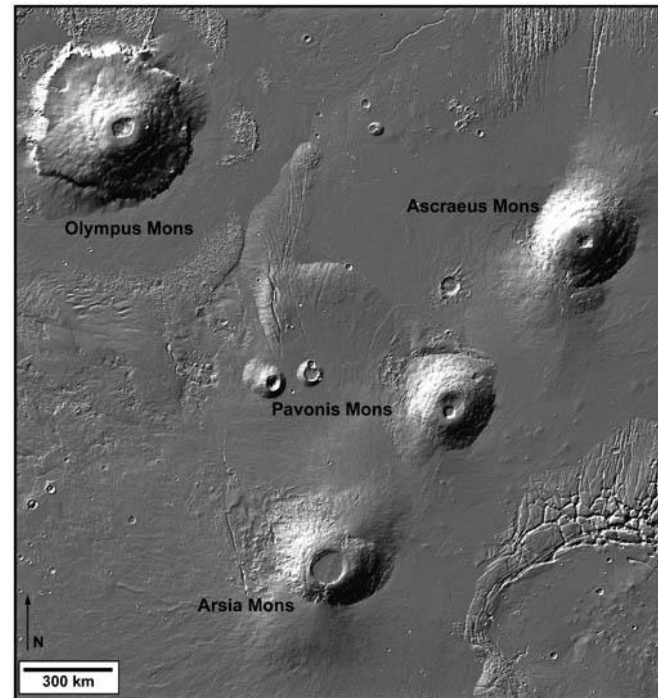
Filamentous microbial communities

*Kelley et al. (2001)*

Other vents → methane

# Mars???

- Mars has a large plateau (Tharsis) with large volcanoes
- Most likely due to hot spots
- But no spreading centers, subduction trenches or arc volcanoes

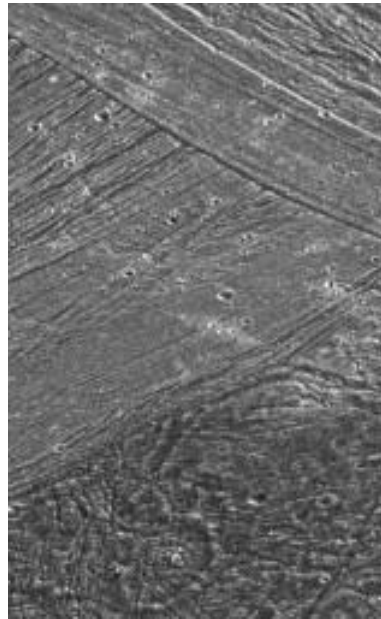


# Why not Venus and Mars?

- Mars?? Probably cooled too fast → crust too thick for convection to develop
- Venus??? Probably too hot → water boiled away from the crust
  - (water acts as a lubricant and decreases melting temps → subduction)

# Jupiter's moon Ganymede???

- Evidence of past movement



[http://csep10.phys.utk.edu/astr161/lect/jovian\\_moons/ganymede.html](http://csep10.phys.utk.edu/astr161/lect/jovian_moons/ganymede.html)



So what????

# Plate tectonics involved in geochemical cycling

Cycling = necessary for life

# Tsunami's

- <https://www.youtube.com/v/Wx9vPv-T51I>
- Practice APES free response 2014#3